Willamette River Basin Temperature TMDL Model: Model Calibration

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Technical Report EWR-02-04

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August, 2004

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Acknowledgments

The Willamette River Temperature TMDL modeling coordinator Jim Bloom and others at the Oregon Department of Environmental Quality provided essential support that was crucial in acquiring the detailed information on the Willamette River system that was necessary for this project. Their efforts are greatly appreciated and were essential to the project's success.

There were many other individuals who were instrumental in providing data compilation and insight into understanding the Willamette River system. They include (not in order of importance): Jim Bloom, Beth Woodward, Dennis Ades, Steve Mrazik, Greg Aldrich, Agnes Lut, and Allen Hamel, all of the Oregon Department of Environmental Quality; Arthur D. Armour, Jim Britton, and Michael Knutson of the U.S. Army Corps of Engineers, Portland District; Jo (Suzanne) Miller, Stewart Rounds, and Annett Sullivan of the U.S. Geological Survey; Antonius Laenen (retired from the USGS) for his work on conducting the Willamette River dye studies in 2002; and Sam Fernald of New Mexico State University for his work on some historical dye studies on the Willamette River.

Abbreviations

Table 1: Report Abbreviations

Abbreviation	Description
AGRIMET	AgriMet, a conjunction of the words "agricultural" and "meteorology", is a satellite-based network of automated agricultural weather stations operated and maintained by the U.S. Bureau of Reclamation.
DEM	Digital Elevation Model
DMR	Discharge Monitoring Reports
DOGAMI	Oregon Department of Geology and Mineral Industries
EWEB	Eugene Water and Electric Board
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GUI	Graphical user interface, usually in the context of the CE-QUAL-W2 preprocessor
HUC	Hydraulic unit code
LASAR	Laboratory Analytical Storage and Retrieval Database
METAR	Traditional weather reporting by the National Weather Service and the Federal Aviation Administration
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
ODEQ	Oregon Department of Environmental Quality
ODF	Oregon Department of Forestry
OMSI	Oregon Museum of Science and Industry
PGE	Portland General Electric
RM	River mile
RAWS	Remote Automated Weather Stations
SRML	Solar Radiation Monitoring Lab, University of Oregon
USACOE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WADOE	Washington State Department of Ecology

Table 2: Computer software and program abbreviations

Computer Software/ Programs	Description
SURFER	Bathymetric and Topographic Contour plotting software
QUAL2E	One-dimensional steady state flow and water quality model
CE-QUAL-W2	Two-dimensional hydrodynamic and water quality model
UNET	One-dimensional hydrologic routing model
HEC	U.S. Army Corps of Engineers, Hydrologic Engineering Center one-dimensional steady and unsteady flow model
FORTRAN	Computer language used for CE-QUAL-W2 and post-processing of model results.

Table 3: CE-QUAL-W2 model geometry variable names

CE-QUAL-W2 terms	Description
IMP	Number of longitudinal segments in model grid
KMP	Number of vertical layers in model grid
ELBOT	Bottom of elevation of grid for specific water body

Introduction

The State of Oregon Department of Environmental Quality (DEQ) is developing a TMDL for temperature in the Willamette River basin shown in Figure 1. The study area included the Willamette River and all major tributaries (except the Tualatin River where a TMDL process was already concluded). A large section of the Columbia River was also modeled to provide adequate boundary representation of tidal flows in the lower Willamette River. The Willamette River below the Oregon City Falls in the Portland metropolitan area has a typical diurnal tidal range of 1 m. The development of a dynamic model of temperature and hydrodynamics of the entire river basin incorporating shading were primary requirements of this modeling study. The model would be used by DEQ to set temperature limits on point source dischargers and to evaluate the impact of management strategies on river temperatures to improve fish habitat. Some of these strategies included modifications of the dam at the Willamette River Falls south of Portland and channel reconfigurations.

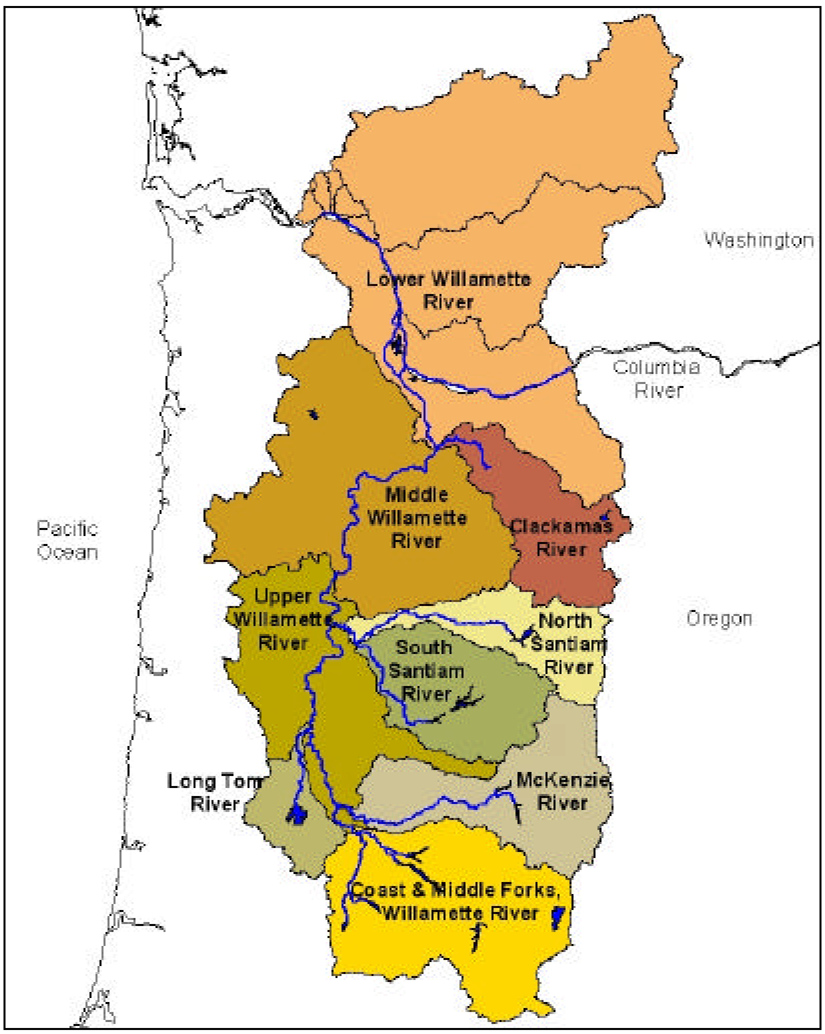

Figure 1: TMDL study area - the Willamette River basin with drainage basins delineated.

CE-QUAL-W2 Version 3.1 (Cole and Wells, 2002), a two dimensional (longitudinal-vertical), laterally averaged, hydrodynamic and water quality model developed by the U.S. Army Corps of Engineers

(USACOE) Waterways Experiments Station, was chosen as the appropriate model tool for this system for the following reasons:

- Dynamic temperature predictive capability
- Dynamic shading prediction based on detailed topographic and vegetative shading information
- Ability of the model to be used for water quality after the temperature study where parameters of interest are algae, periphyton, pH, dissolved oxygen
- Ability to model complex hydraulic flow paths with multiple interconnected branches using hydraulic elements (weirs, pumps, spillways) between branches
- Ability to evaluate the stratification potential of deep pools in the Willamette River where water quality and temperature data have shown significant stratification
- Ability to model estuary hydrodynamics
- Ability to model an entire river basin including upstream deep-density stratified reservoirs
- Public domain executable and source code for quality-assurance and testing

The river basin model was originally divided into several reaches. Individual models were developed for each reach. These reaches were (see also Figure 2):

- **Columbia River** - from Beaver Army Terminal (Columbia River Mile 53.8) to Bonneville Dam (RM 144.5) (Willamette River enters the Columbia River at Columbia River Miles 87 and 101);
- **Tidal Willamette River** – Lower Willamette River from mouth to Willamette Falls (RM 26.5), including the Willamette Channel and the Multnomah Channel;
- **Non-tidal Willamette River** – Willamette Falls (RM 26.5) to confluence of Coast and Middle Forks (RM 187); this section was divided further into the following reaches: Middle Willamette from the Willamette Falls (RM 26.5) to the city of Salem (RM 85); Upper Willamette from the City of Salem (RM 85) to the confluence of Coast and Middle Forks (RM 187)
- **Clackamas River** up to River Mill Dam/Estacada Lake (RM 26);
- **Santiam River** (all 12 miles), North Santiam River up to Detroit Dam (RM 49), South Santiam River up to Foster Dam (RM 38);
- **Long Tom River** to Fern Ridge Dam (RM 26);
- **McKenzie River** to RM 56, and South Fork McKenzie River to Cougar Dam (RM 4);
- **Middle Fork Willamette** to Dexter Dam (RM 17), Fall Creek to Fall Creek Dam (RM 7);
- **Coast Fork Willamette** to Cottage Grove Dam (RM 30), Row River to Dorena Dam (RM 7.5);
- **Columbia Slough** in the tidal portion of the Willamette River (about 9 miles in length)

The models were set-up for each section of the Willamette basin as described in Annear et al. (2004a), the models were calibrated to field data and management strategies were evaluated as described in Annear et al (2004b).

This report outlines the model calibration of each of these model sections or elements for both the calibration time periods. The calibration period for each model section differs due to the availability of boundary condition data. The model management simulation scenarios (Annear et al, 2004b) also required boundary condition data that extended past the calibration periods.

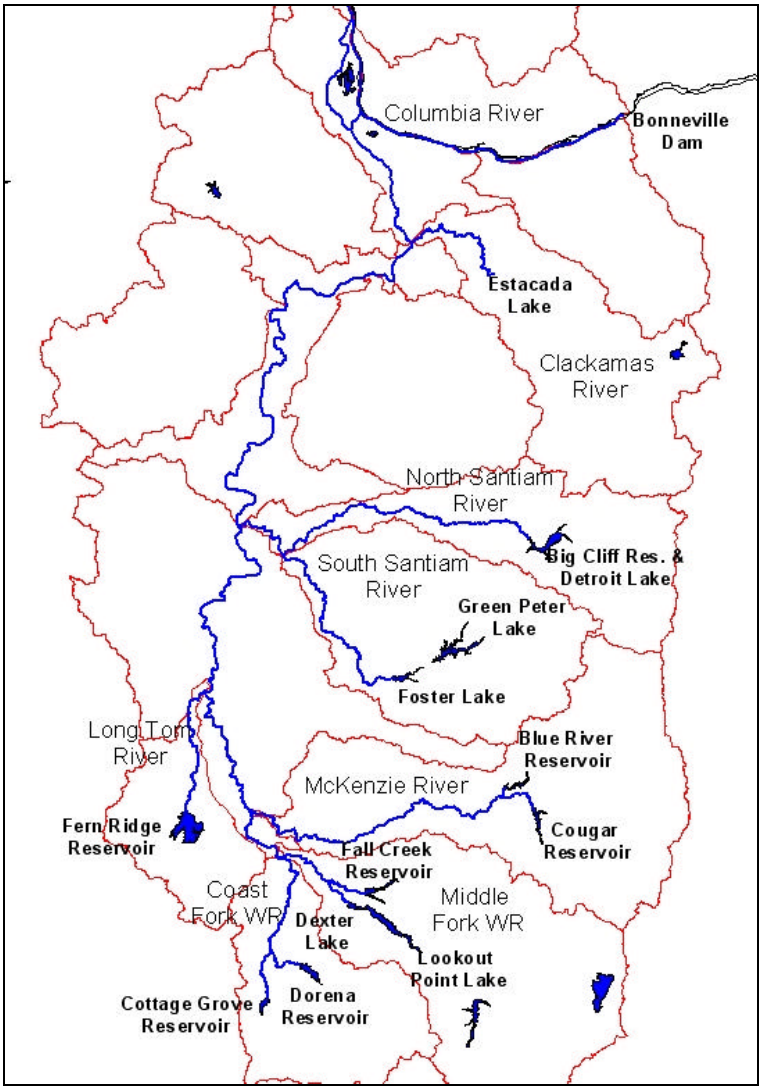

Figure 2: Willamette River and modeled tributaries.

This report is divided into model reaches. Within each model reach the following items are discussed:

- Hydrodynamics calibration
  - Flow
  - Water level, stage
  - Channel widths
  - Time of travel and dye studies, where available
- Temperature calibration
  - Continuous temperature time series data
  - Daily maximum temperature time series data
- Summary

Lower Willamette River / Columbia River

Introduction

The Willamette River system is a 30,800 km^2 watershed that drains through the Lower Willamette River from RM 0 to RM 26.8 (Willamette Falls), Figure 3. The river passes through the Portland metropolitan area before its confluence with the Columbia River at Columbia RM 106. The Columbia River is tidally influenced from the Pacific Ocean to the tailrace of the Bonneville Dam at RM 145. The Lower Willamette River is also tidally influenced below Willamette Falls at RM 26.8. The model calibration periods are from July 26, 2001 to September 28, 2001, and from April 1, 2002 to October 1, 2002.

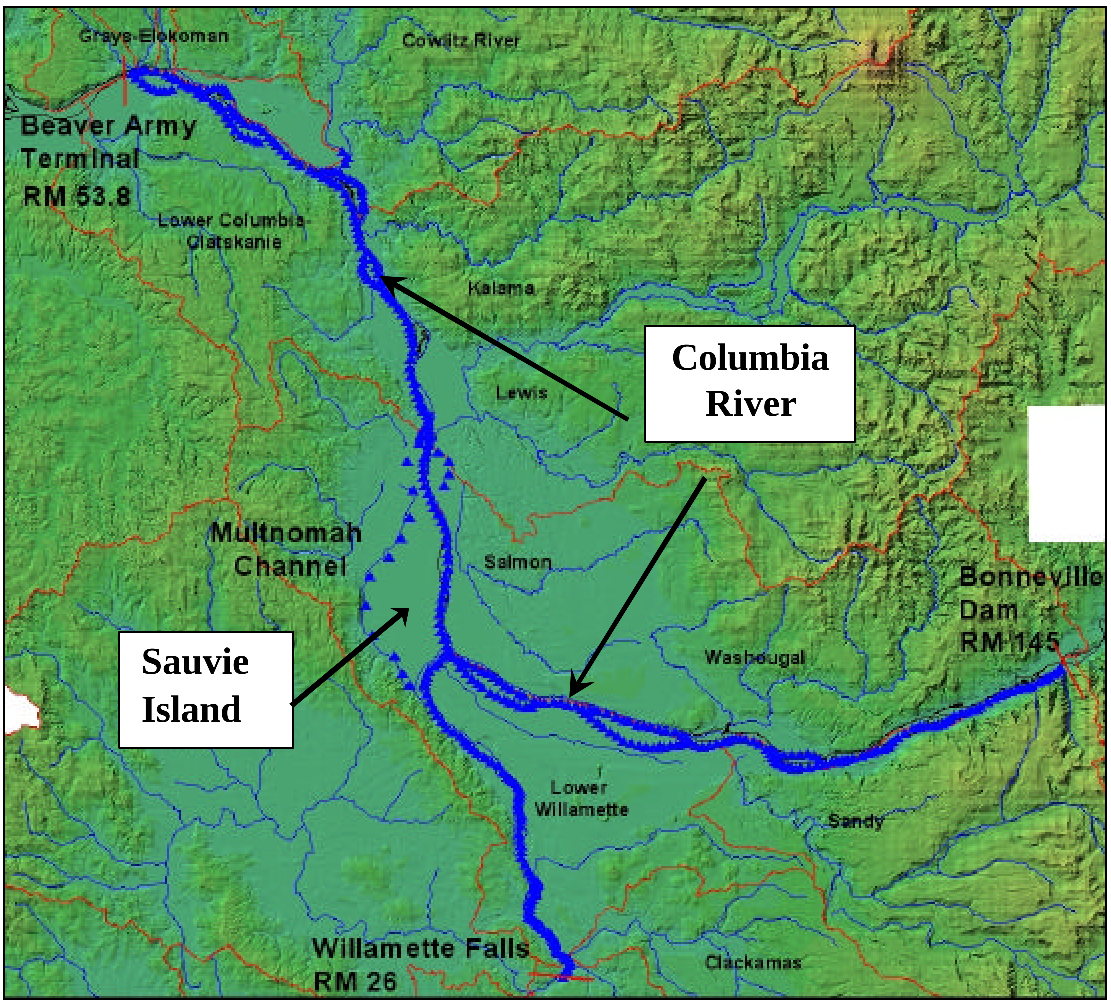

Figure 3: Lower Willamette River basin region

Hydrodynamics

The process of hydrodynamics calibration includes having accurate dynamic flow and head boundary conditions, detailed model bathymetry, and adjusting model friction using the Manning's friction factor. For these model comparisons, once the model bathymetry and boundary conditions were established, the model friction factors were adjusted until there was reasonable model-data agreement for water level and flow data. Manning's *n*, or friction coefficient, was the only model coefficient used for calibrating water level and flow rate predictions with data. For all simulation years Manning's *n* was calibrated to a value range of 0.022 to 0.035 for the whole model domain.

Flow and Water Surface Elevation

The Lower Willamette River model has six gage stations with continuous water surface elevation data and one gage stations with flow data for calibrating the model. Figure 4 shows a map of the basin with the gage site locations and Table 4 shows a list of the gage sites, their RM, and corresponding model segment.

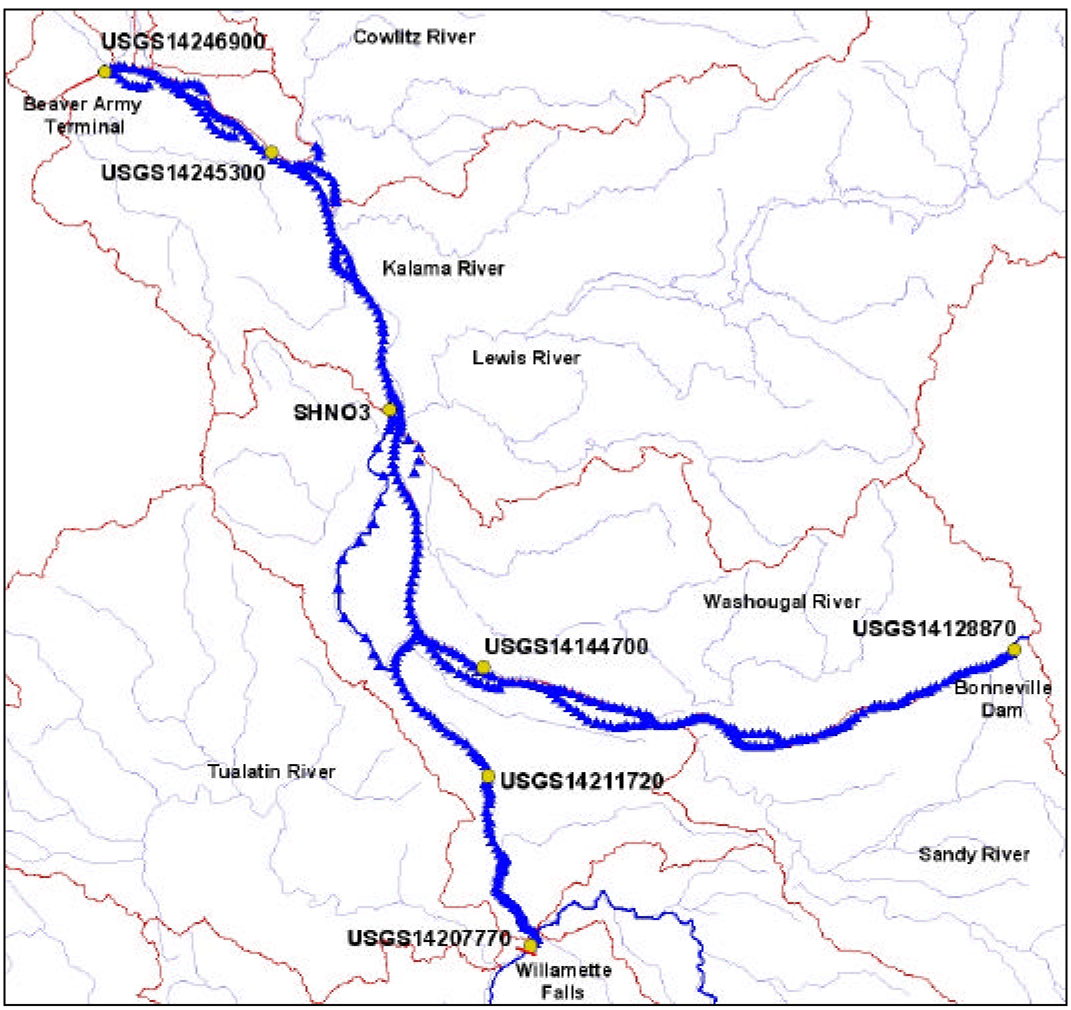

Figure 4: Lower Willamette River hydrodynamic calibration site locations

Table 4: Lower Willamette River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14211720	Willamette at Portland, OR	12.70	66	WL
USGS 14207770	Willamette below Willamette Falls	26.48	2	WL
USGS 14144700	Columbia River at Vancouver, WA	106.50	223	WL
ACOE SHNO3	Columbia River at St. Helens, OR	85.75	270	WL
USGS 14245300	Columbia River at Longview, WA	66.20	315	WL
USGS 14128870	Columbia River below Bonneville Dam, OR	144.50	118	WL
USGS 14246900	Columbia at Beaver Army Terminal	53.00	347	Q

The hydrodynamics were calibrated moving downstream on the Willamette River and Columbia River to incorporate the tidal effects on the Columbia River. The downstream boundary condition was based on water surface elevation at Beaver Army Terminal, RM 53.8. Flow data recorded at this site was then used as calibration check. The data recorded at Longview, WA (USGS 14245300) was found to be unreliable so model data comparisons are not presented.

Year 2001

Manning's *n*, or friction coefficient, was the only model coefficient used for calibrating water level and flow rate predictions with data. Manning's *n* values could be adjusted on a segment by segment basis and were calibrated to values between 0.022 and 0.035.

The error statistics for the year 2001 Lower Willamette River hydrodynamic calibration were shown in Table 5. Plots of model predicted water levels and flow were shown in Figure 5 through Figure 10. In general figures show the water level and flow model matching well with data. The model is similar the diurnal fluctuations in water level due to tidal forcing. Model predictions generally match up well with data. Model predicted outflows at Beaver Army Terminal had a root mean square error of 56.0 m^3/s, which is relatively small considering daily flows can approach 10,000 m^3/s. Water levels in the Lower Willamette River are affected by tides. Since the boundary condition at Beaver Army Terminal is well described with gaging station data, the model was able to replicate tidal fluctuations.

Table 5: Lower Willamette River hydrodynamic calibration statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14246900	53.00	347	4208	-43.3	43.4	56.0
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14207770	26.48	2	2976	0.05	0.13	0.19
USGS 14211720	12.70	66	2976	0.03	0.12	0.17
USGS 14128870	144.50	118	5952	0.04	0.09	0.12
USGS 14144700	106.50	223	5952	0.04	0.13	0.17

ACOE SHNO3	85.75	270	7996	0.09	0.12	0.16

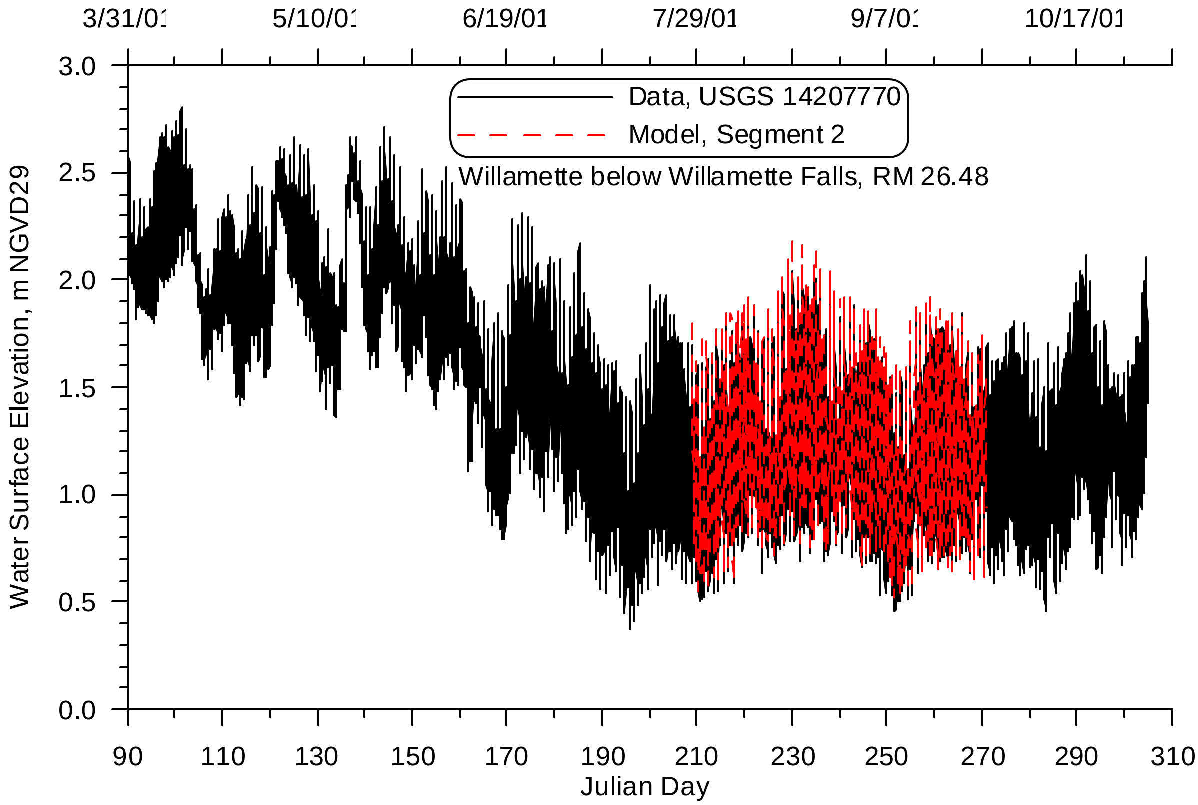

Figure 5: Willamette River below the Willamette Falls model-data water level comparison, 2001.

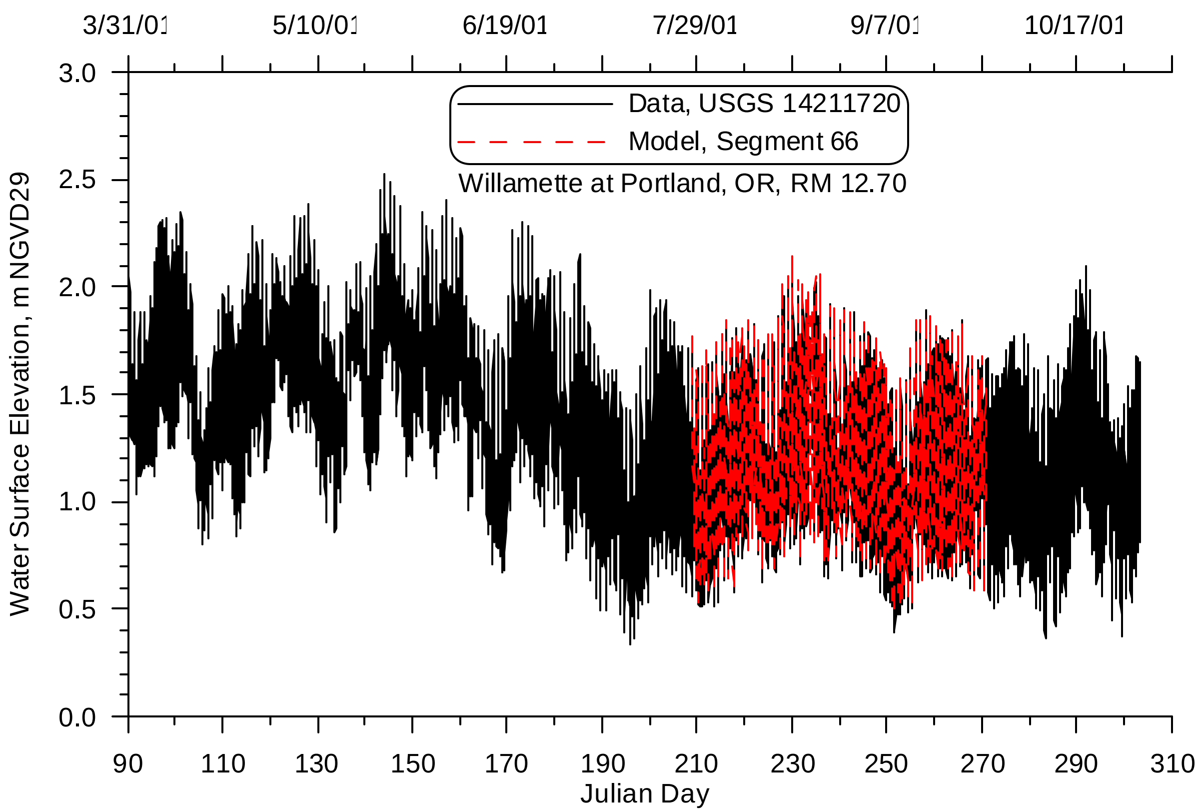

Figure 6: Willamette River at Portland model-data water level comparison, 2001

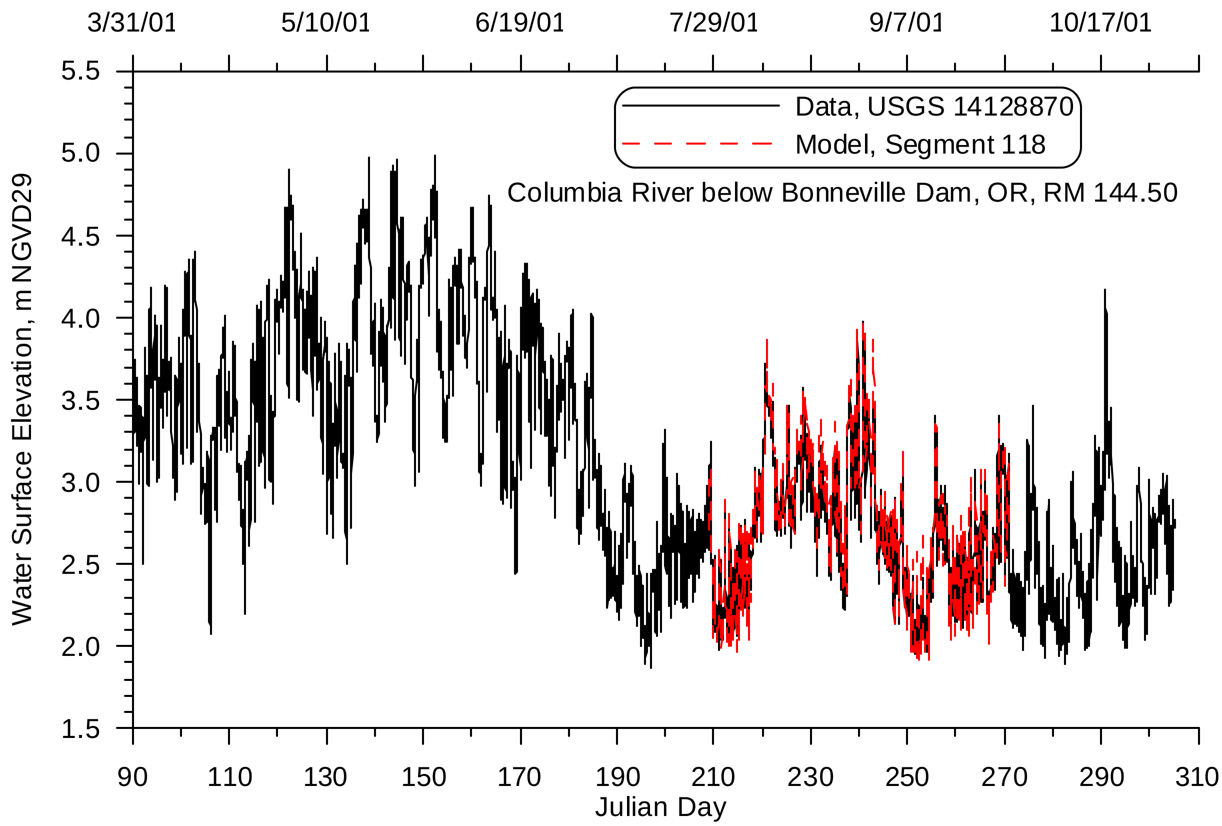

Figure 7: Columbia River below Bonneville Dam model-data water level comparison, 2001

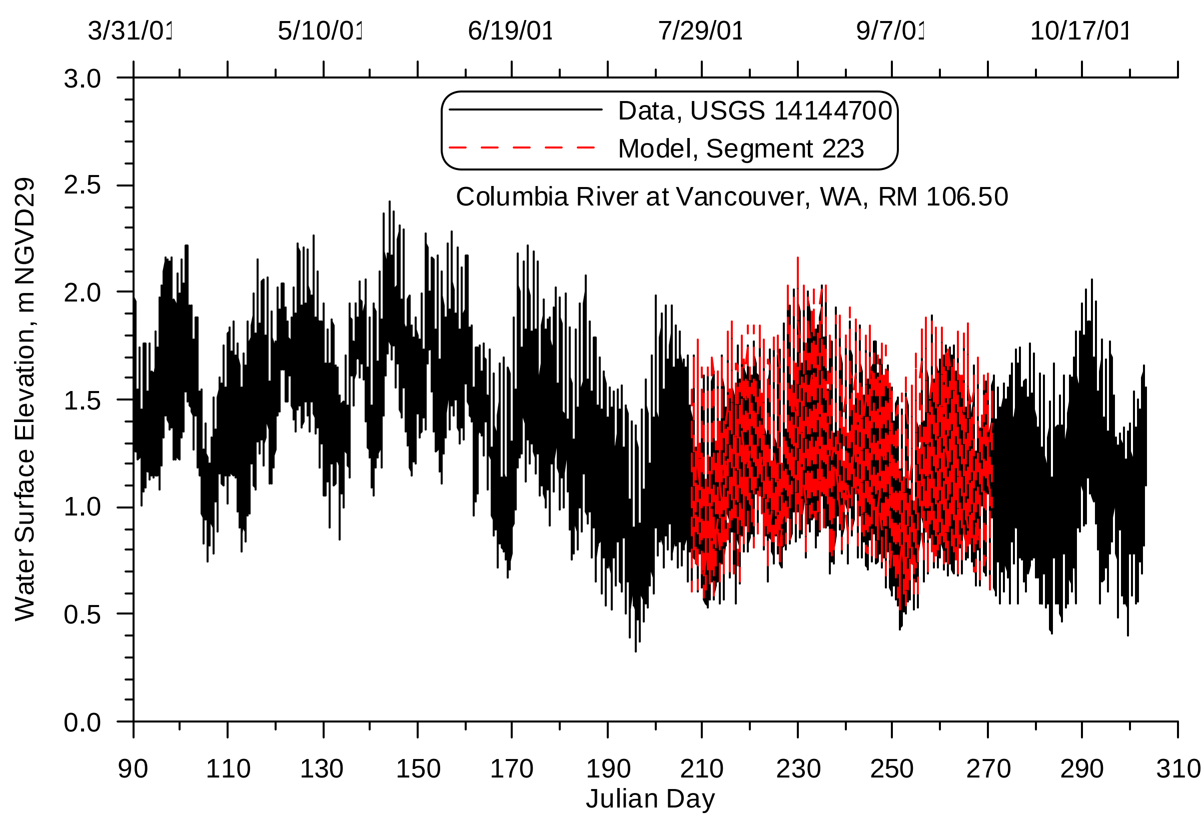

Figure 8: Columbia River at Vancouver, WA model-data water level comparison, 2001

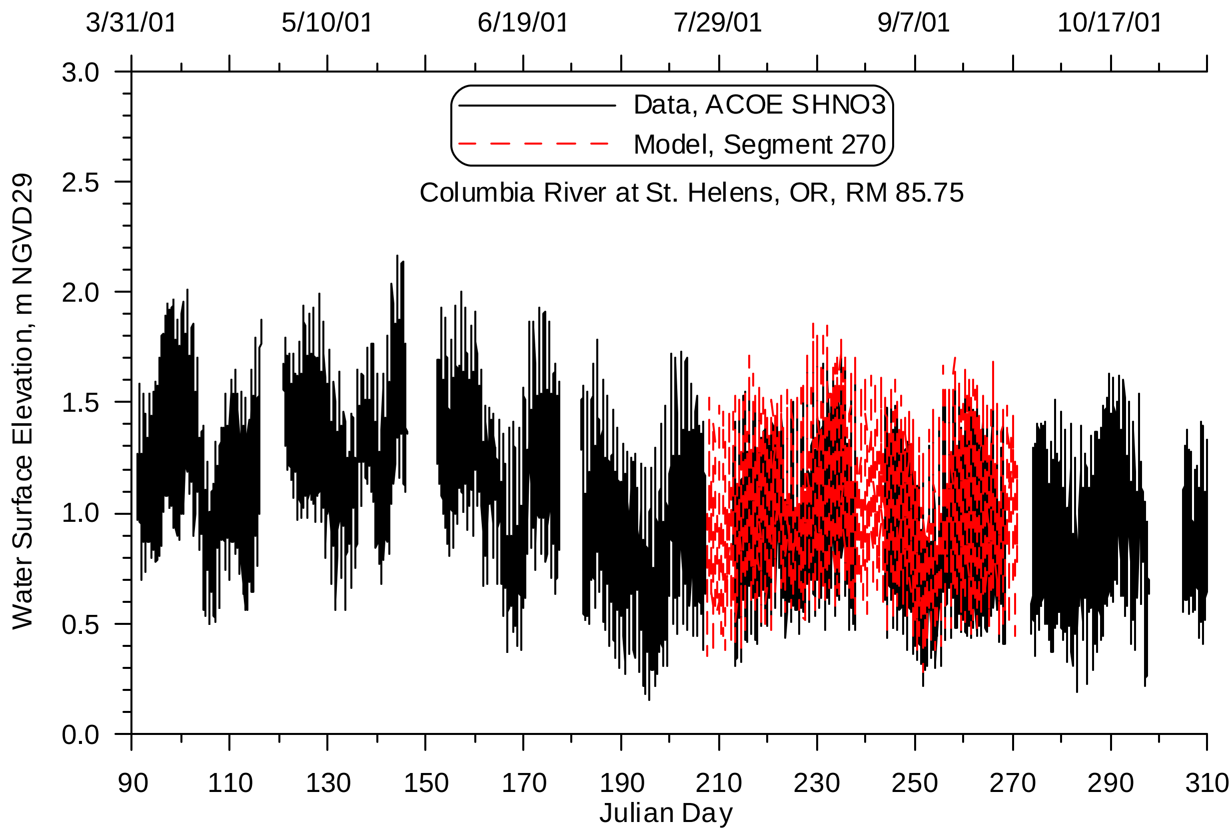

Figure 9: Columbia River at St. Helens, OR model-data water level comparison, 2001

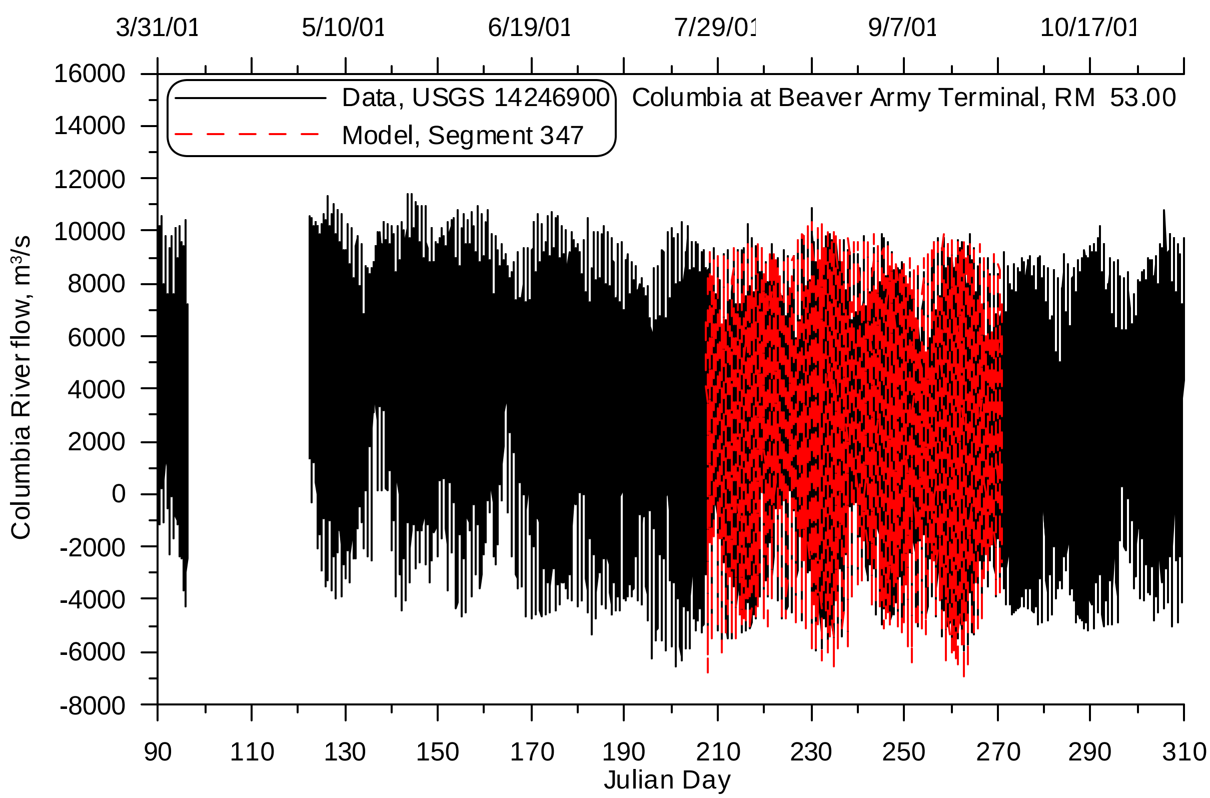

Figure 10: Columbia River at Beaver Army Terminal model-data flow comparison, 2001

Year 2002

Table 6 shows model-data error statistics for the hydrodynamic calibration of the Lower Willamette River model for 2002. Figure 11 through Figure 16 compare model predicted water level and flow with data. The figures show there is good model-data agreement for all sites with the exception of a high flow event in late April. The model is capturing the diurnal water level fluctuations due to tidal forcing. As in 2001, the model does well predicting water level and flow predictions during the summer and fall. There are a couple high flow events during the spring where the model does not do quite as well predicting water levels at a couple locations. During the summer into early fall months when water temperature predictions are more critical, the model predictions match well with data.

Table 6: Lower Willamette River hydrodynamic calibration statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14246900	53.00	347	17446	-14.5	14.9	28.4
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14207770	26.48	2	8352	-0.20	0.23	0.40
USGS 14211720	12.70	66	8352	-0.13	0.15	0.21
USGS 14128870	144.5	118	4175	-0.01	0.11	0.15
USGS 14144700	106.50	223	16704	-0.07	0.12	0.18
ACOE SHNO3	85.75	270	22128	0.03	0.14	0.19

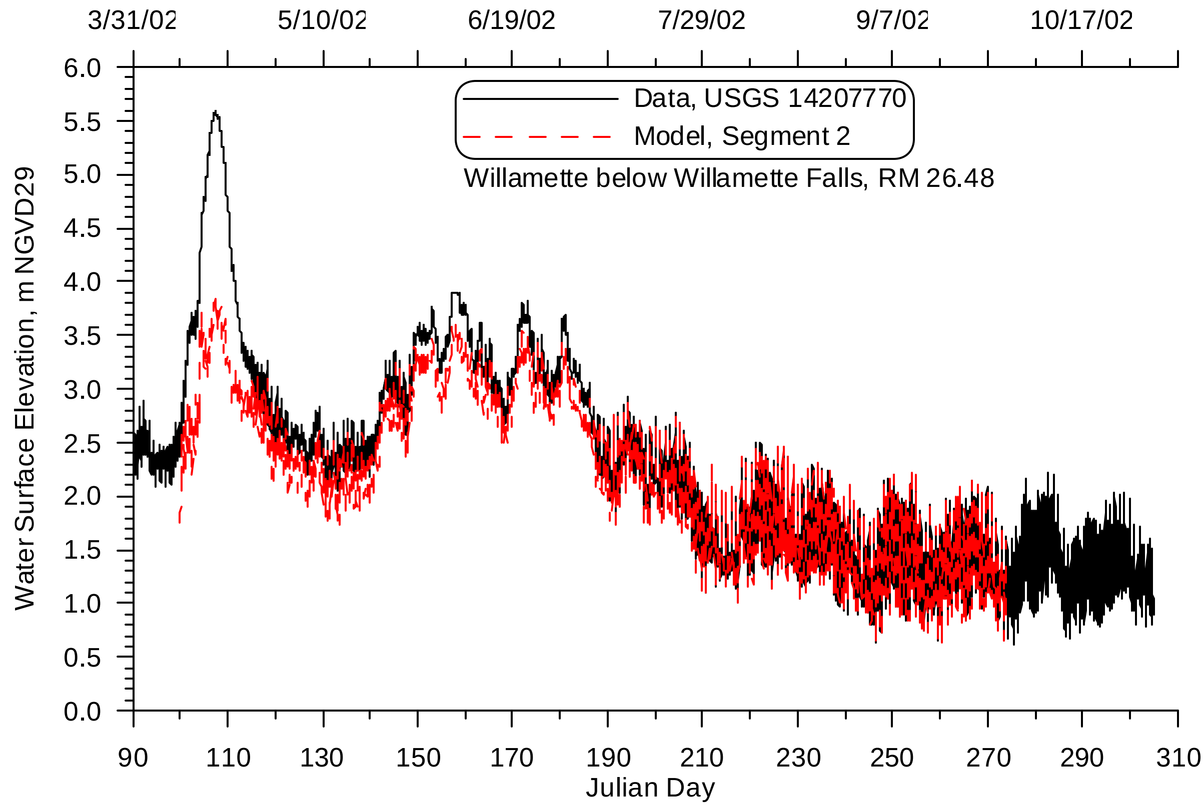

Figure 11: Willamette River below the Willamette Falls model-data water level comparison, 2002

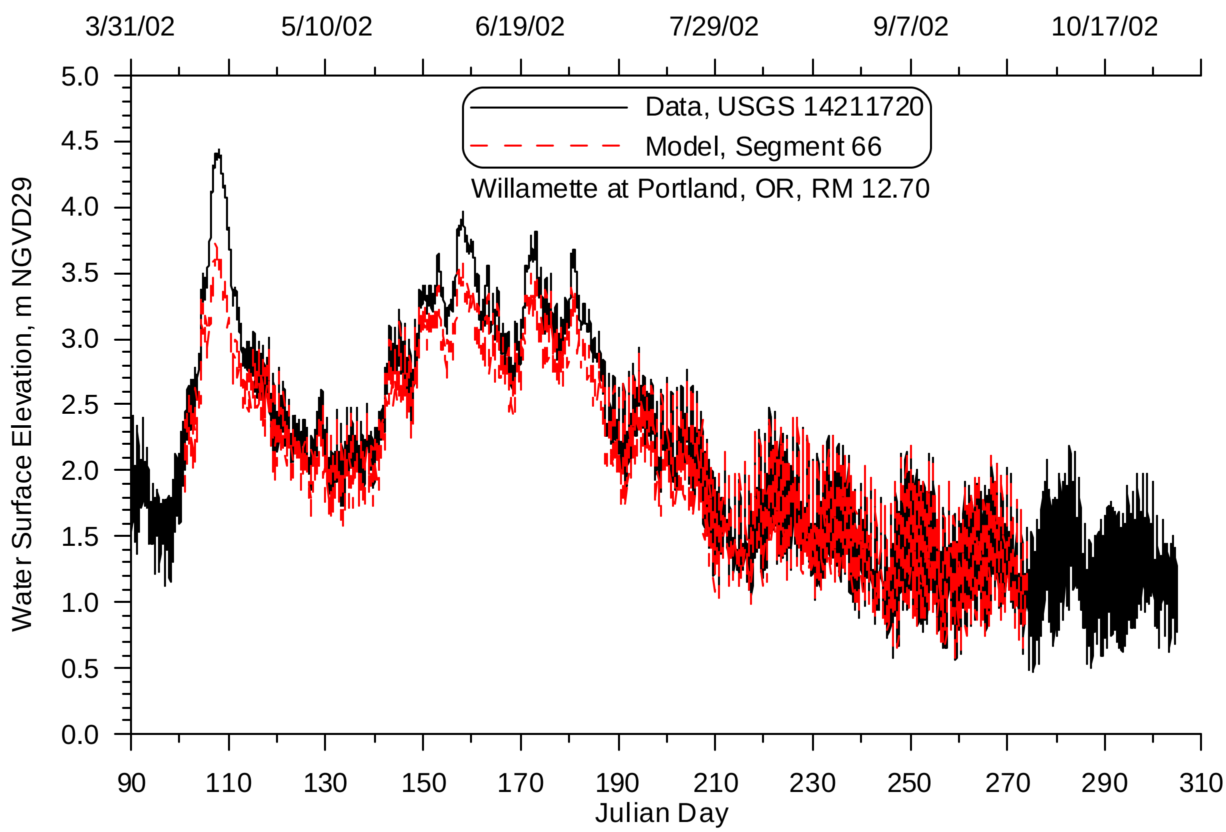

Figure 12: Willamette River at Portland model-data water level comparison, 2002

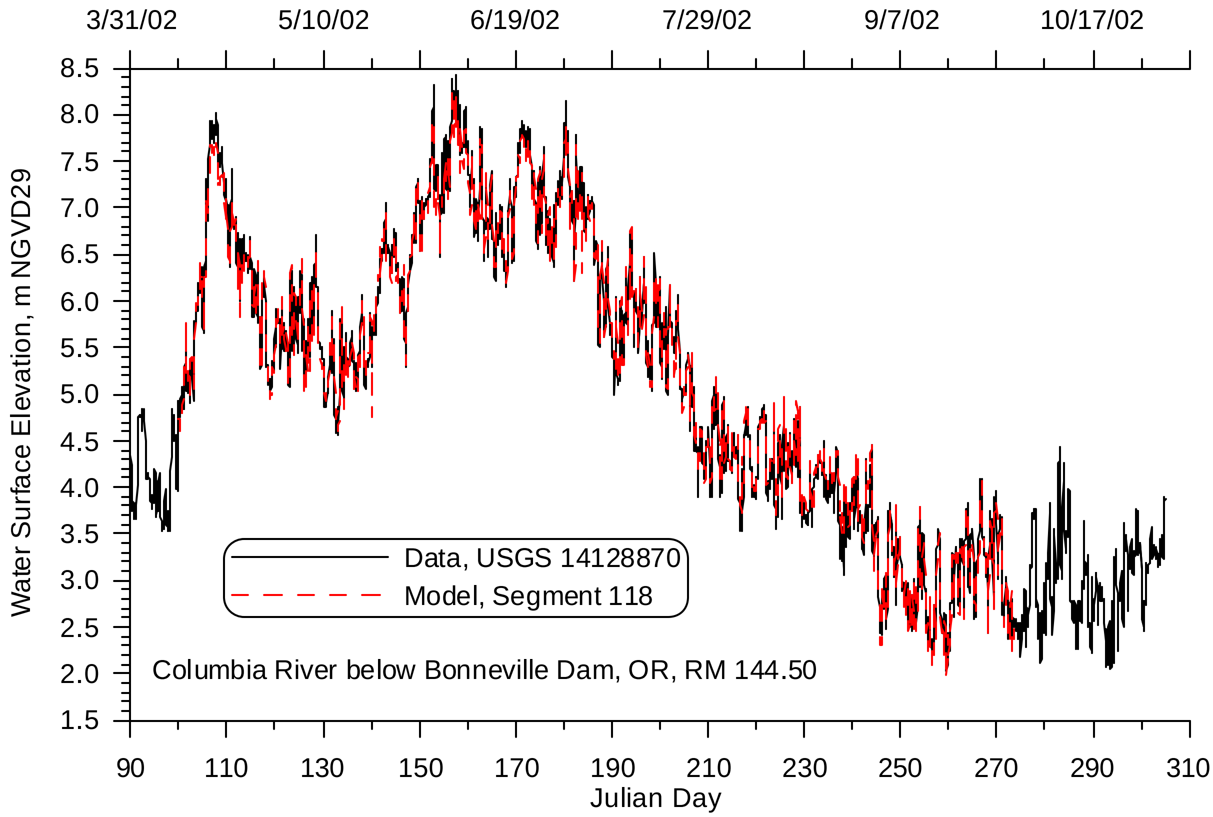

Figure 13: Columbia River below Bonneville Dam model-data water level comparison, 2002

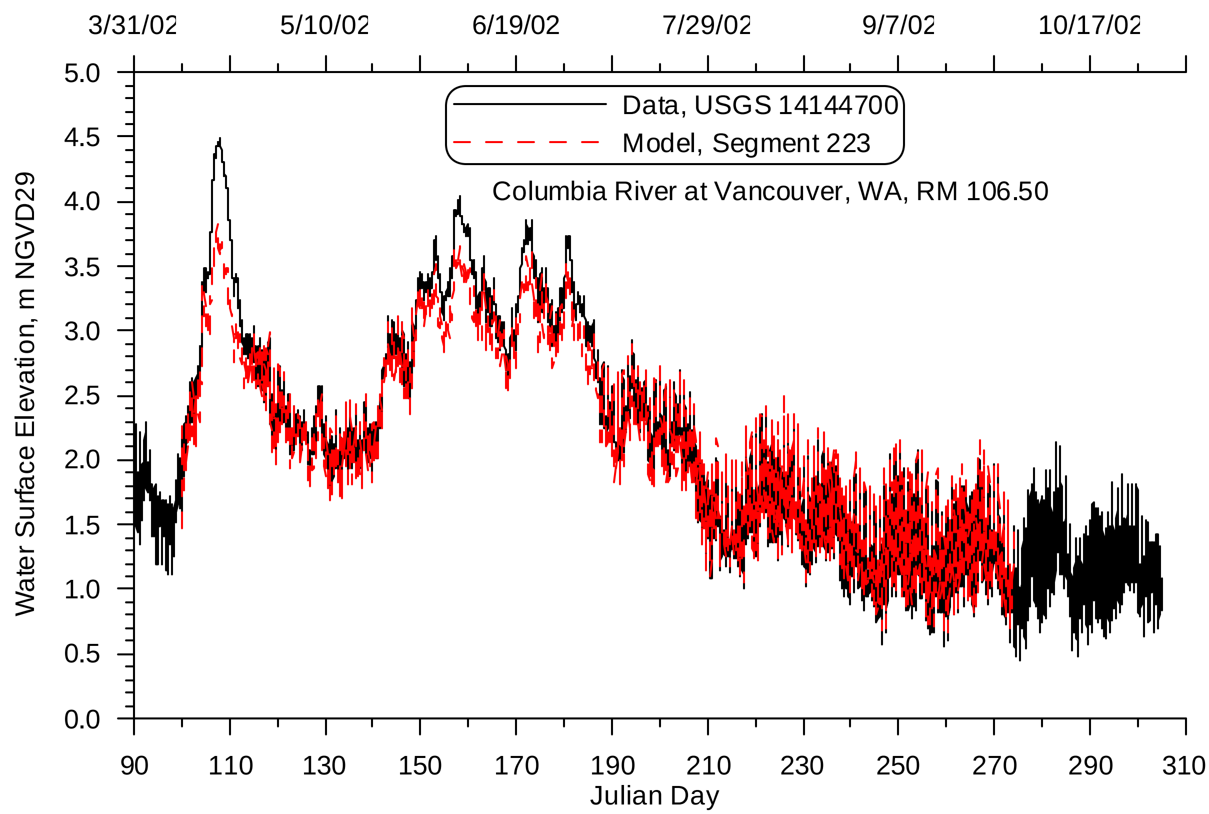

Figure 14: Columbia River at Vancouver, WA model-data water level comparison, 2002

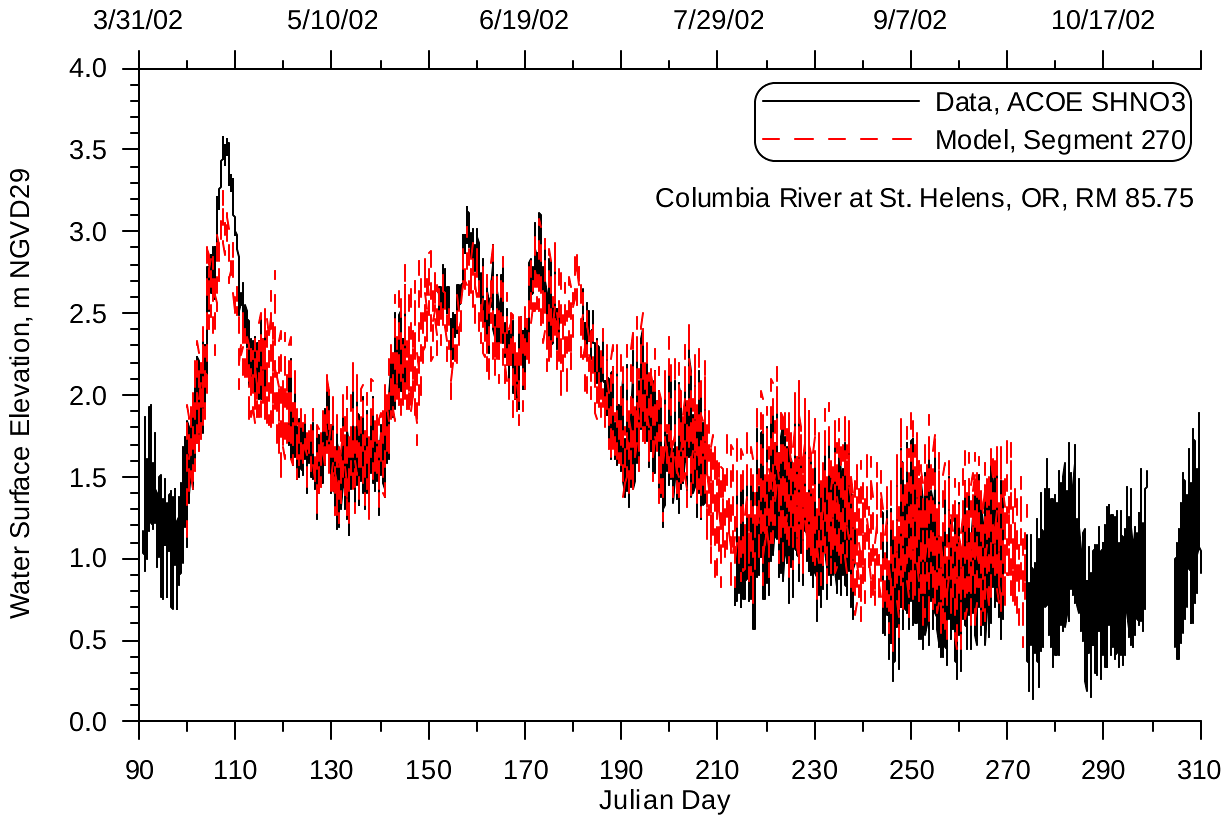

Figure 15: Columbia River at St. Helens, OR model-data water level comparison, 2002

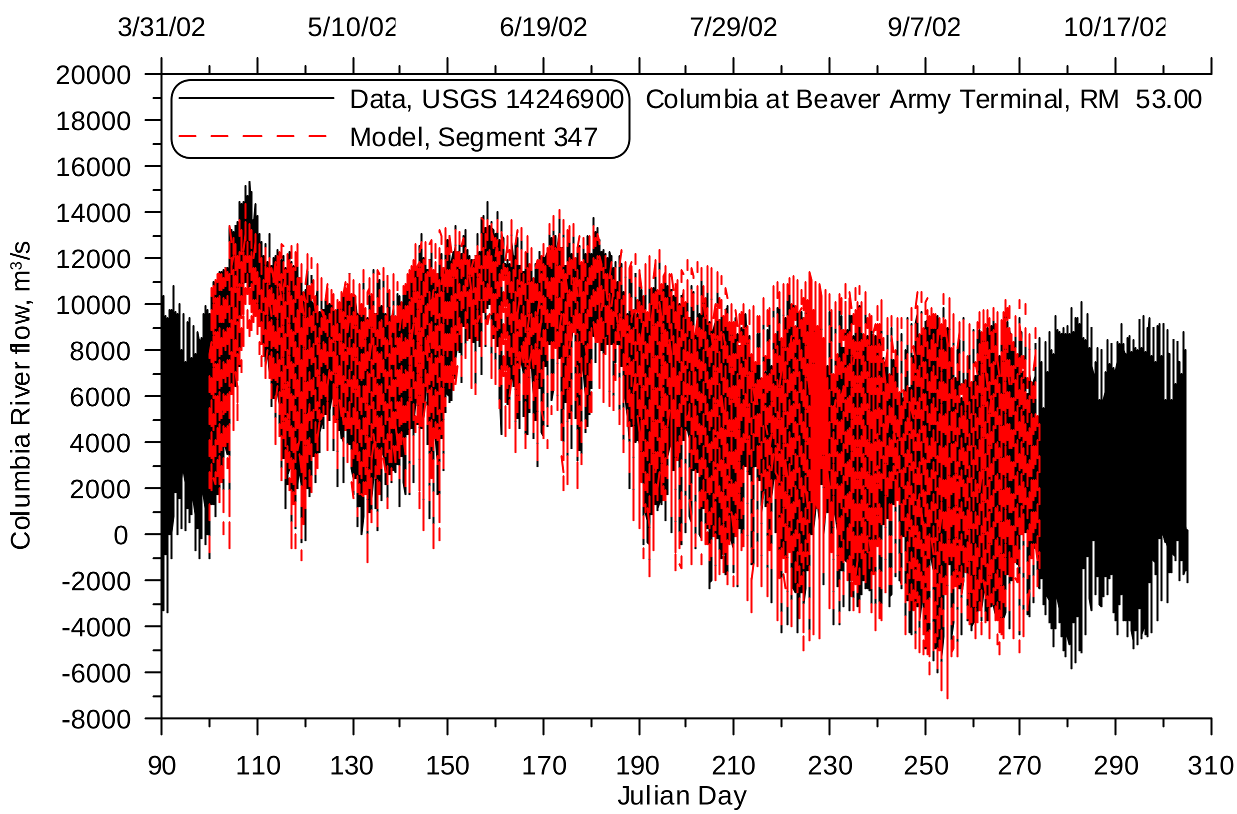

Figure 16: Columbia River at Beaver Army Terminal model-data flow comparison, 2002

Water Temperature

There are a total of seventeen monitoring sites which recorded temperatures in 2001 and 2002 on either an hourly or half-hourly basis. Figure 17 shows a map of the model region with the temperature monitoring site locations identified. Table 7 list the monitoring site descriptions, RM location and corresponding model segment.

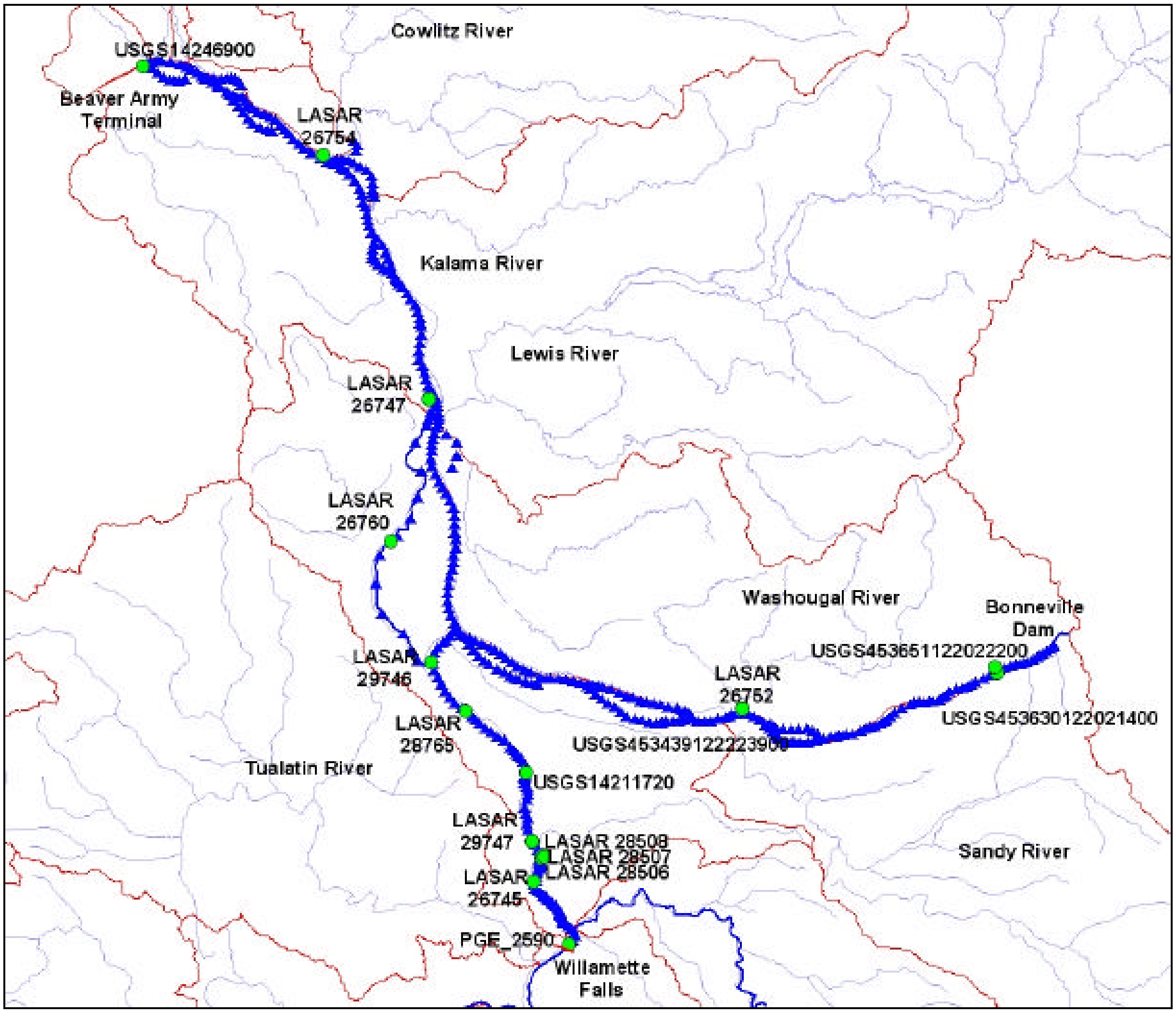

Figure 17: Lower Willamette River temperature calibration site locations

Table 7: Lower Willamette River temperature calibration sites

Site ID	Site Description	RM	Model Segment
PGE_2590	PGE Downstream of W. Falls Sample Set A and B	26.24	2
LASAR 26745	Willamette River at Roehr Waterfront Park	20.75	33
LASAR 28506	Willamette River at RM 18.76, North of Deer Island	18.83	45
LASAR 28507	Willamette River u/s of Kellogg Creek WWTP Outfall	18.75	46
LASAR 28508	Willamette River d/s of Kellogg Creek WWTP Outfall	18.59	48
LASAR 29747	Willamette River at Waverly Country Club	17.38	52

Site ID	Site Description	RM	Model Segment
USGS 14211720	Willamette at Portland, OR	12.70	66
LASAR 28765*	Willamette River at Saint John's Bridge	7.14	83
LASAR 29746	Willamette River u/s of Oregon Steel Mills	3.20	91
LASAR 26760	Multnomah Channel d/s of Gilbert River	11.10	107
USGS 453651122022200	Columbia River Right Bank near Skamania, WA	140.40	134
USGS 453630122021400	Columbia River Left bank, at Dodson OR (Warrendale)	140.40	134
USGS 453439122223900	Columbia River Right Bank at Washougal, WA	121.75	187
LASAR 26752	Columbia River at RM 122.5	121.50	188
LASAR 26747	Columbia River d/s of Multnomah Channel	85.50	271
LASAR 26754	Columbia River at RM 66.8	67.00	314
USGS 14246900	Columbia at Beaver Army Terminal	53.00	347

*Data starts after end of simulation period

The model was calibrated by comparing the continuous temperature data and model results but since the model will be used for running model scenarios examining the daily maximum temperature model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

The Lower Willamette River model was well described with boundary condition data and does well in predicting temperature. Residence time was fairly short, particularly in the Columbia River, and temperatures were largely controlled by inflow temperatures at the model boundaries. Since the hydrodynamics were calibrated first, the only calibration parameter used in modeling temperature was light extinction, which was set to a value of 0.6 m^{-1}.

Error statistics comparing model predicted temperatures with continuous temperature data were shown in Table 8. Figure 18 through Figure 29 show plots of model predicted temperature and data. The figures show there are minor diurnal fluctuations and then there are 10 to 14 day fluctuations due to passing weather patterns. Continuous temperature error statistics were below 0.75 ^oC for the Lower Willamette River model.

Table 8: Lower Willamette River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
PGE_2590 A	26.24	2	1524	0.03	0.35	0.42
PGE_2590 B	26.24	2	1524	-0.16	0.36	0.45
LASAR 26745 Shallow	20.75	33	1524	-0.08	0.44	0.74
LASAR 26745 Deep	20.75	33	1524	-0.14	0.42	0.74
LASAR 26760	11.10	107	160	-0.19	0.22	0.27
USGS4 53651122022200	140.40	134	1524	0.02	0.13	0.22
USGS 453630122021400	140.40	134	1315	0.02	0.07	0.16

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 453439122223900	121.75	187	1320	-0.14	0.22	0.65
USGS 14129400 LASAR 26752	121.50	188	3048	-0.11	0.20	0.63
LASAR 26747	85.50	271	163	-0.42	0.42	0.49
LASAR 26754	67.00	314	989	0.47	0.50	0.61
USGS 14246900	53.00	347	6096	-0.12	0.31	0.76

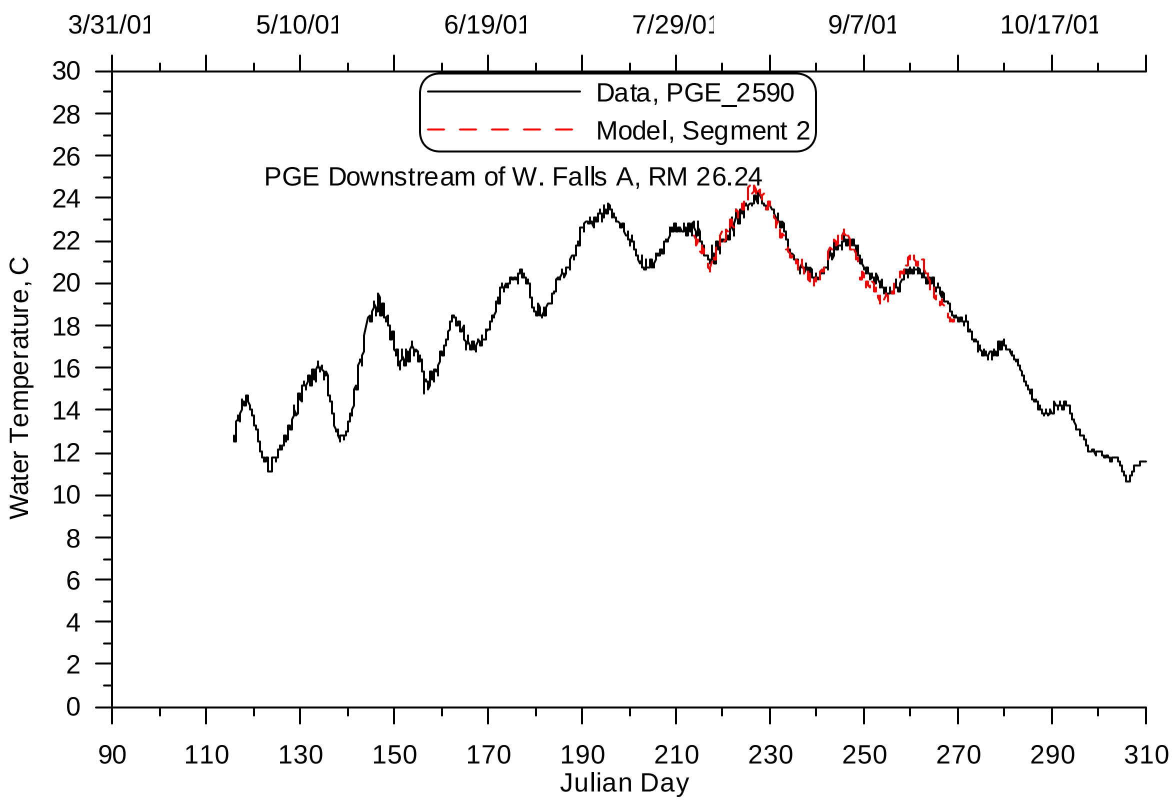

Figure 18: Willamette River downstream of the Willamette Falls site A model-data continuous temperature comparison, 2001

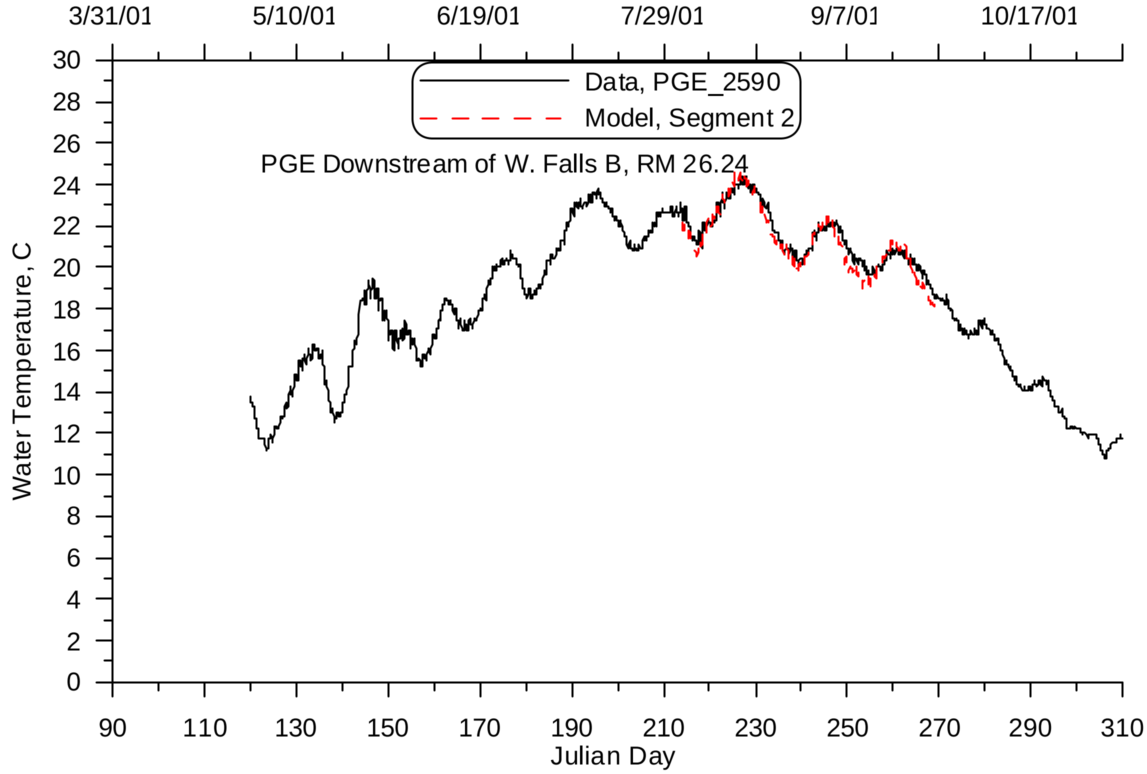

Figure 19: Willamette River downstream of the Willamette Falls site B continuous model-data temperature comparison, 2001

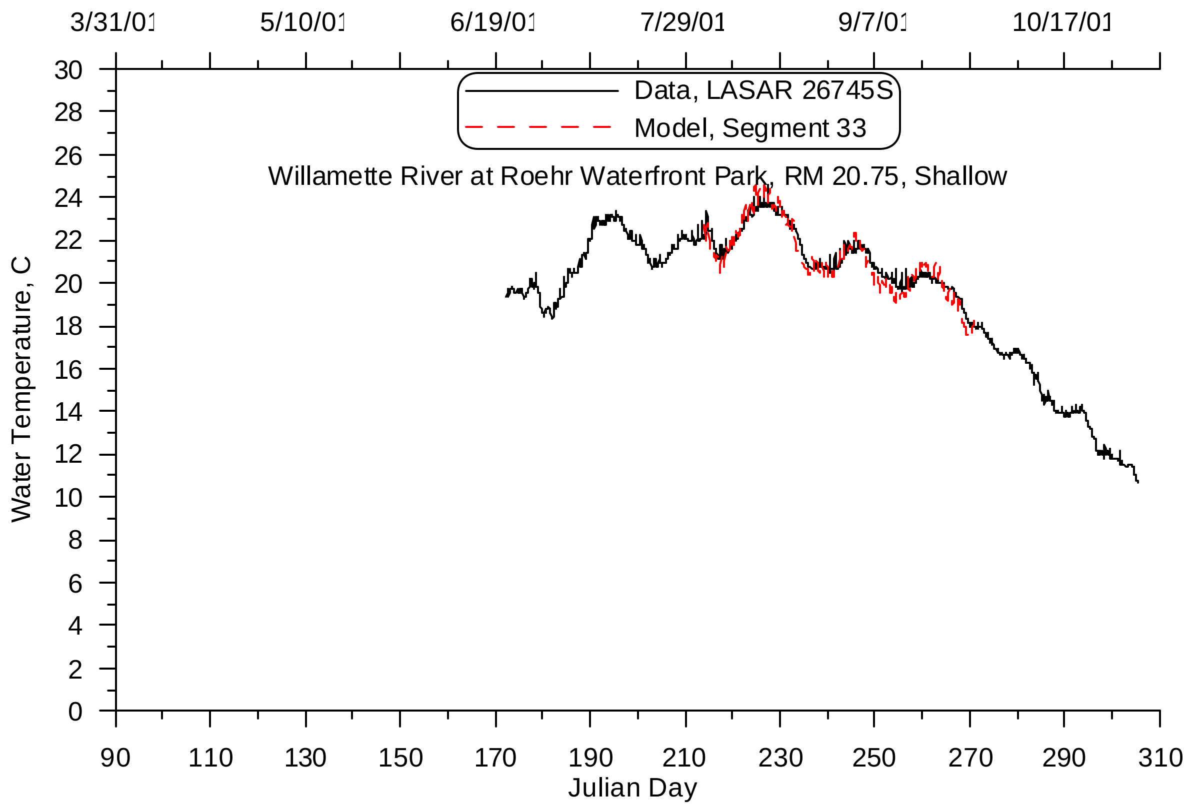

Figure 20: Willamette River at Roehr Waterfront Park (shallow) model-data continuous temperature comparison, 2001

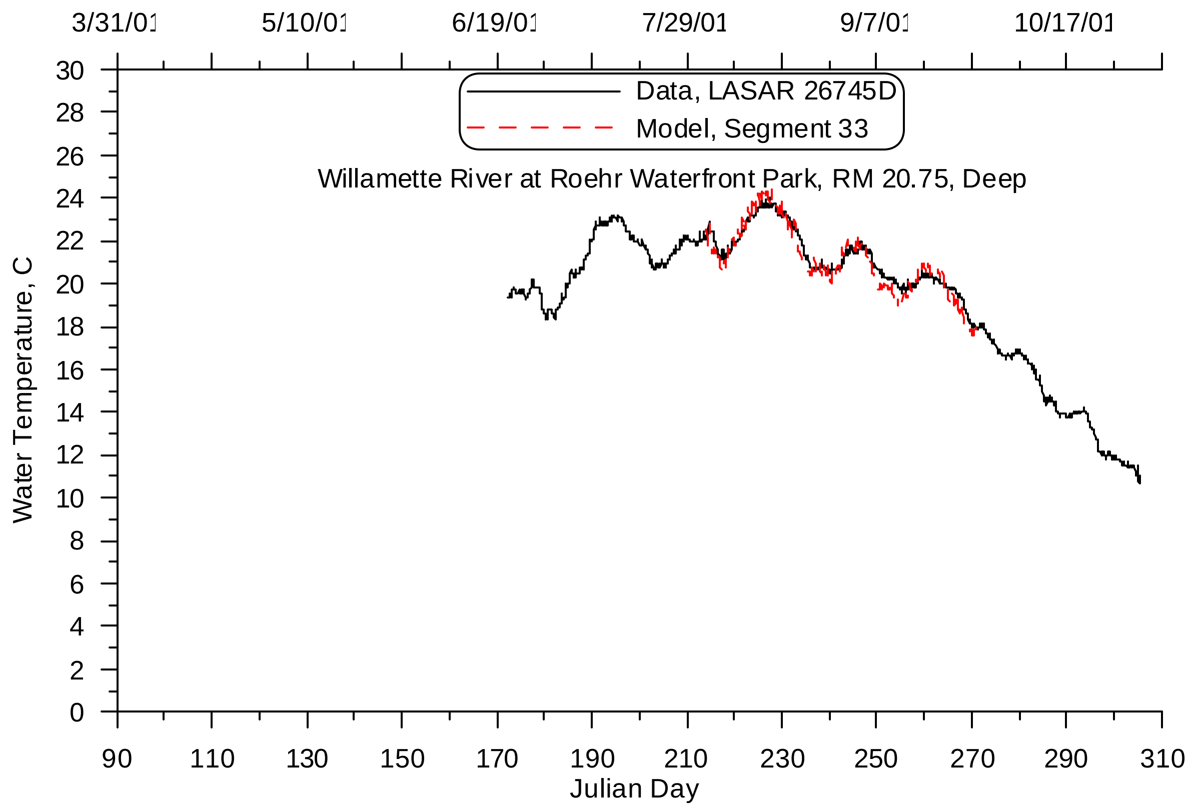

Figure 21: Willamette River at Roehr Waterfront Park (deep) model-data continuous temperature comparison, 2001

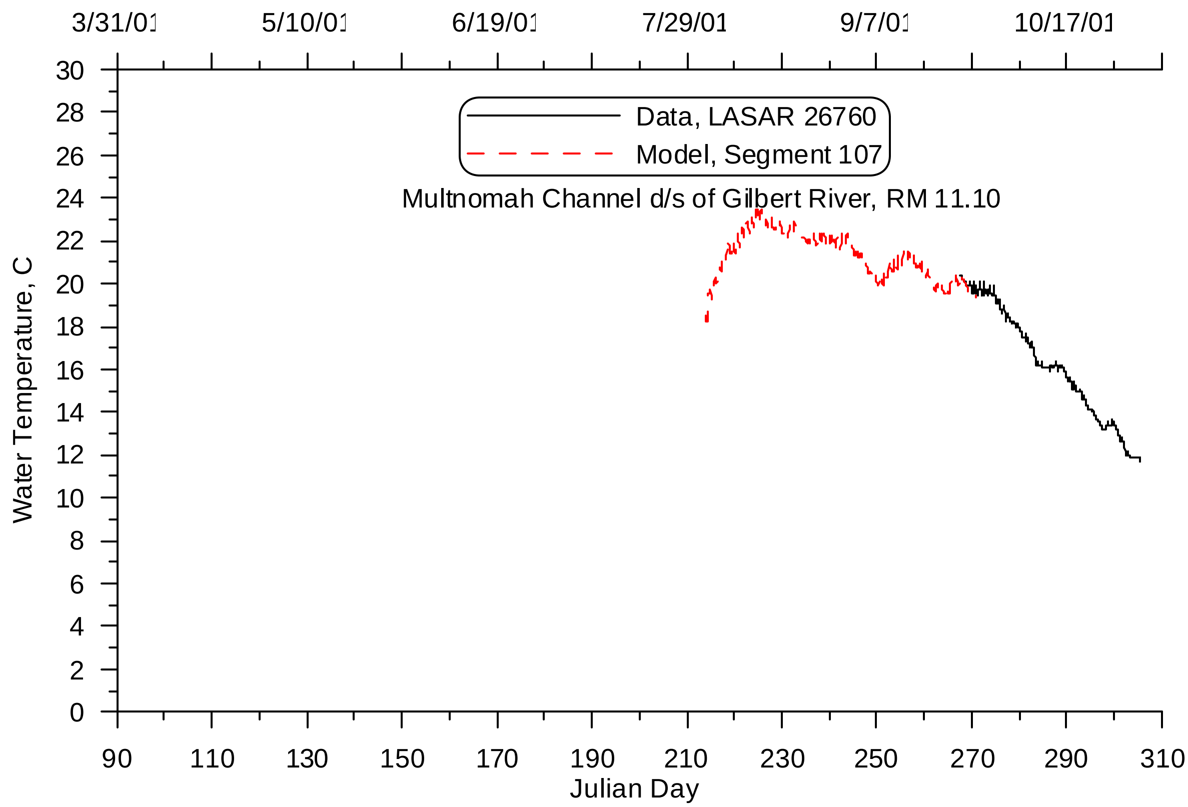

Figure 22: Multnomah Channel downstream of Gilbert River model-data continuous temperature comparison, 2001

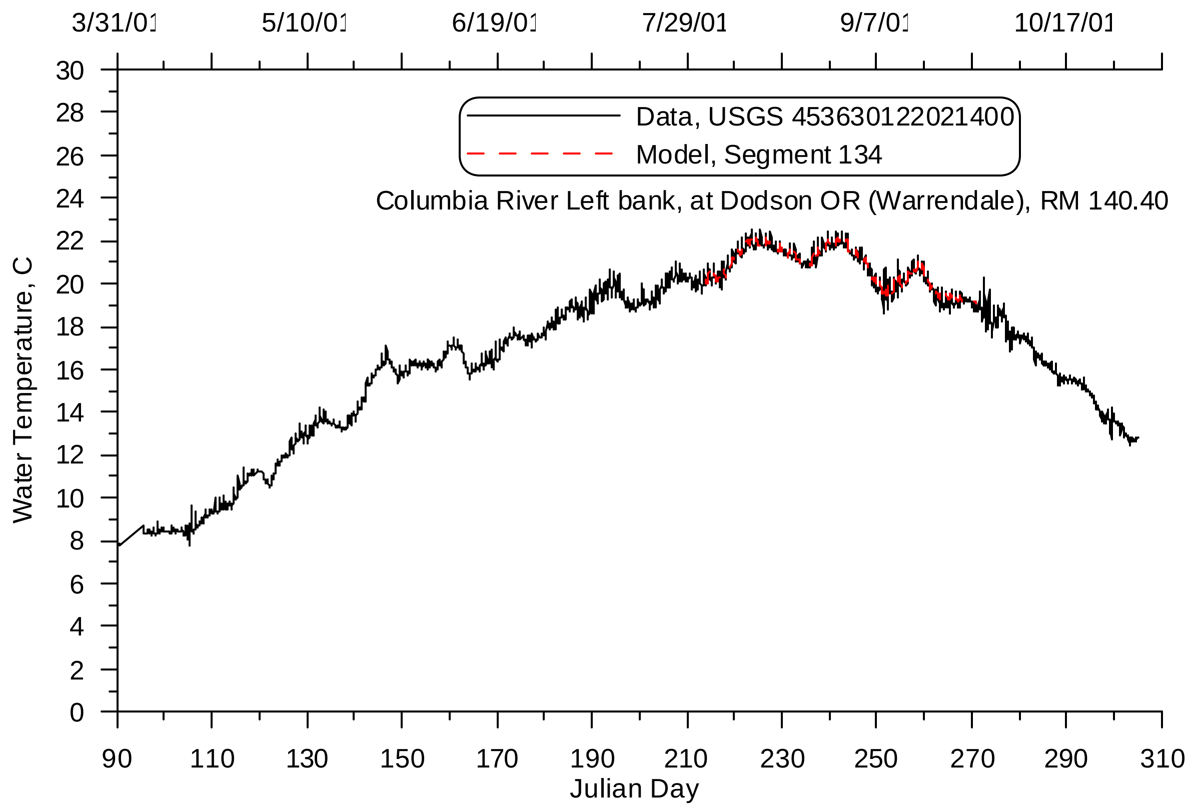

Figure 23: Columbia River Left Bank at Dodson continuous model-data temperature comparison, 2001

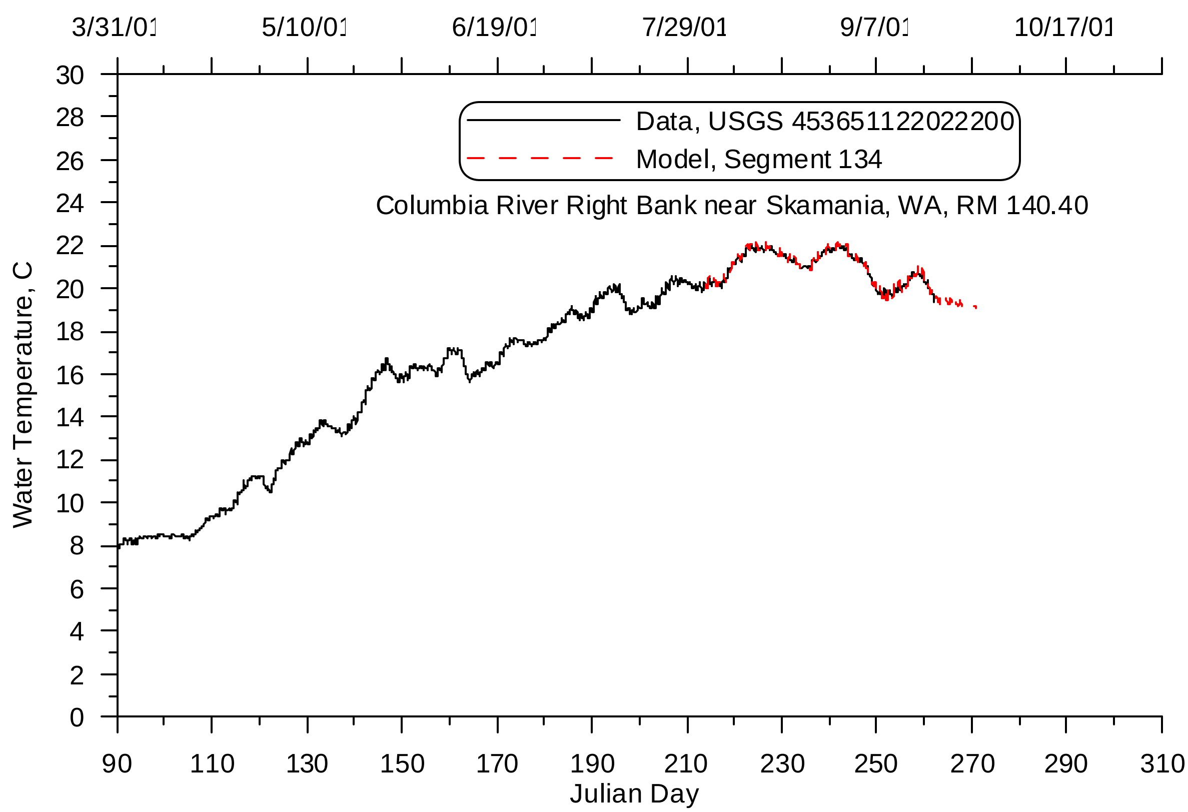

Figure 24: Columbia River Right Bank near Skamania model-data continuous temperature comparison, 2001

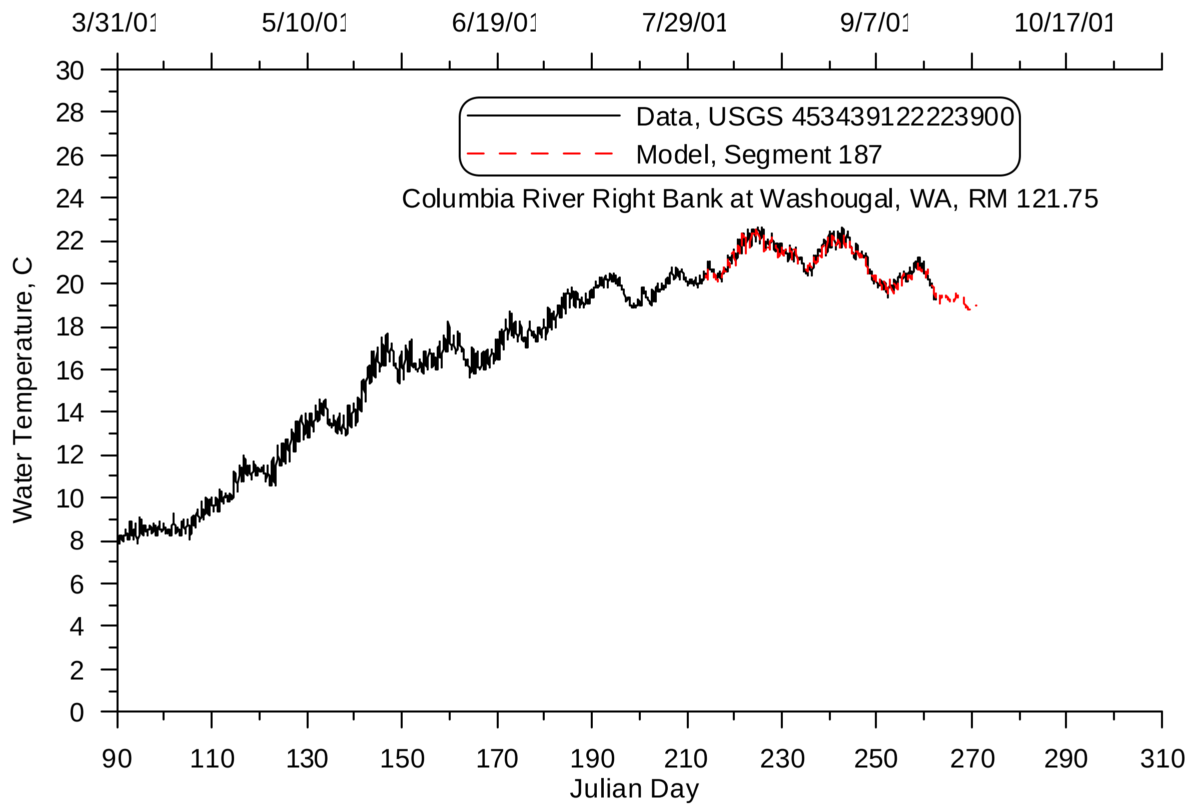

Figure 25: Columbia River at Washougal, WA model-data continuous temperature comparison, 2001

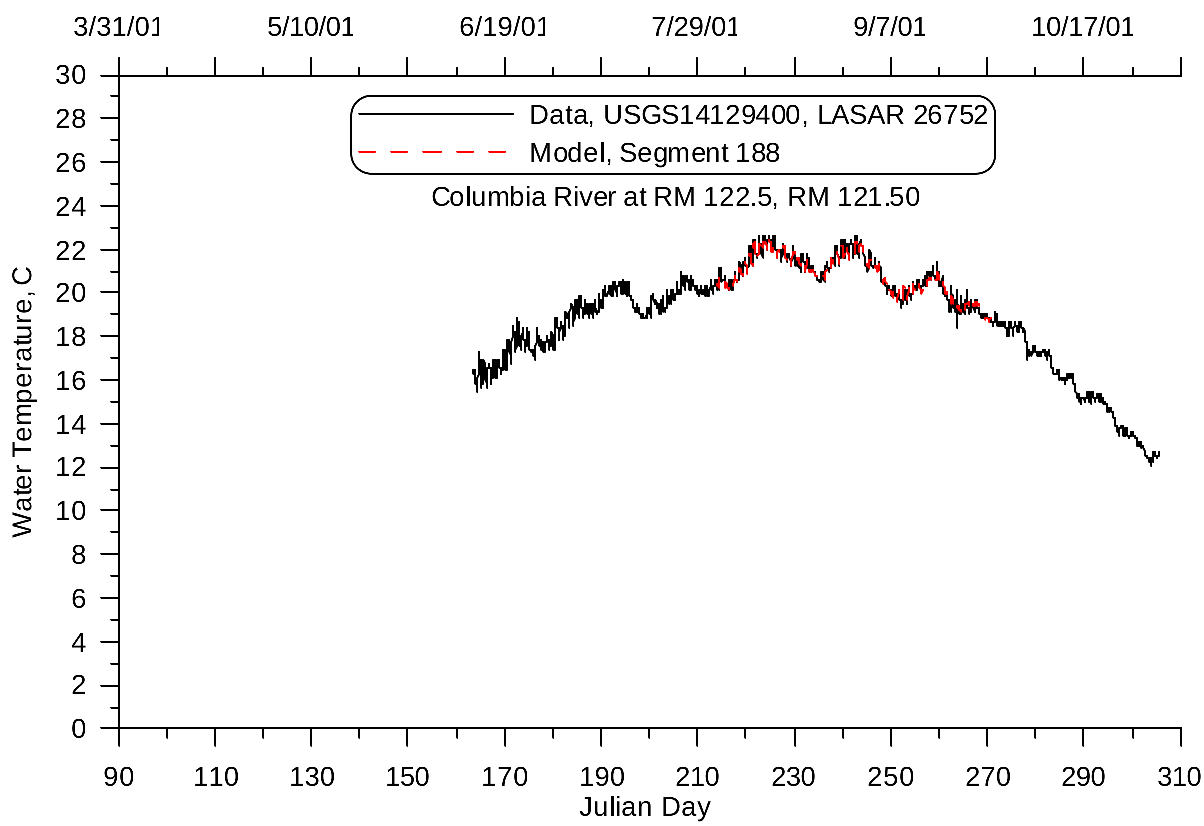

Figure 26. Columbia River at RM 122.5 model-data continuous temperature comparison, 2001

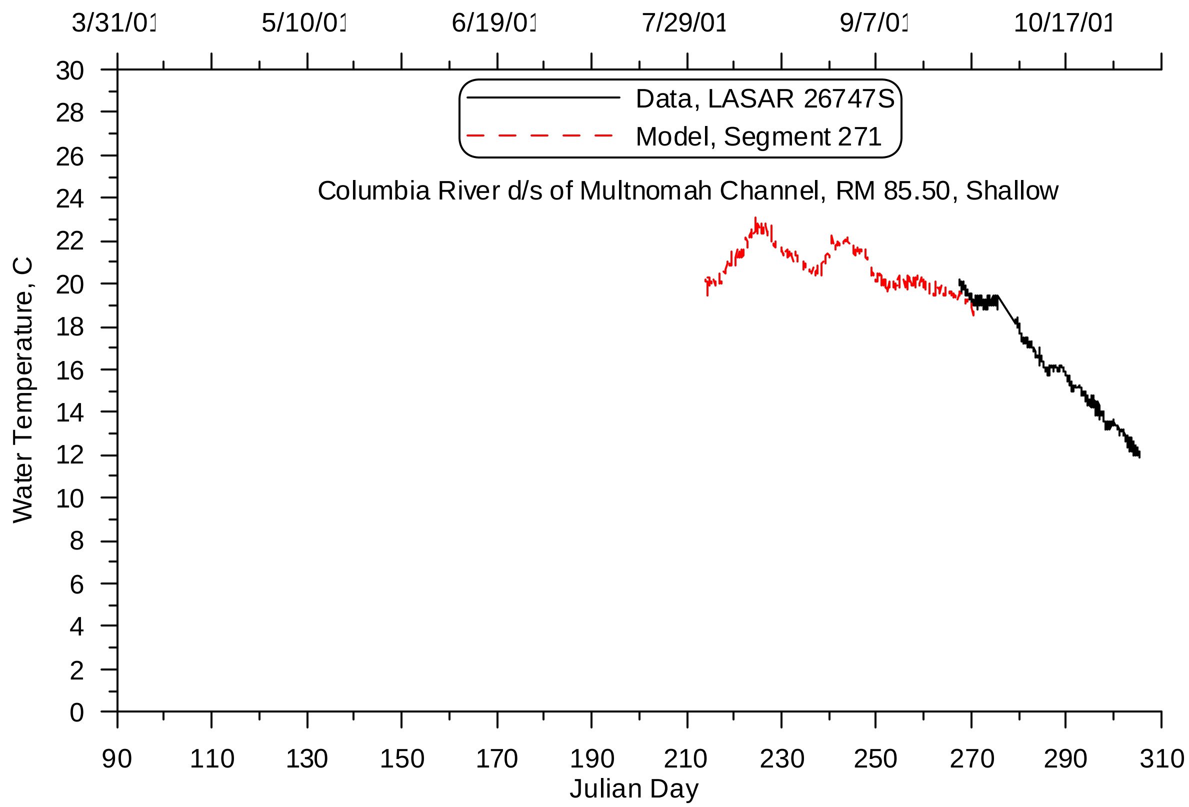

Figure 27: Columbia River d/s Multnomah Channel model-data continuous temperature comparison, 2001

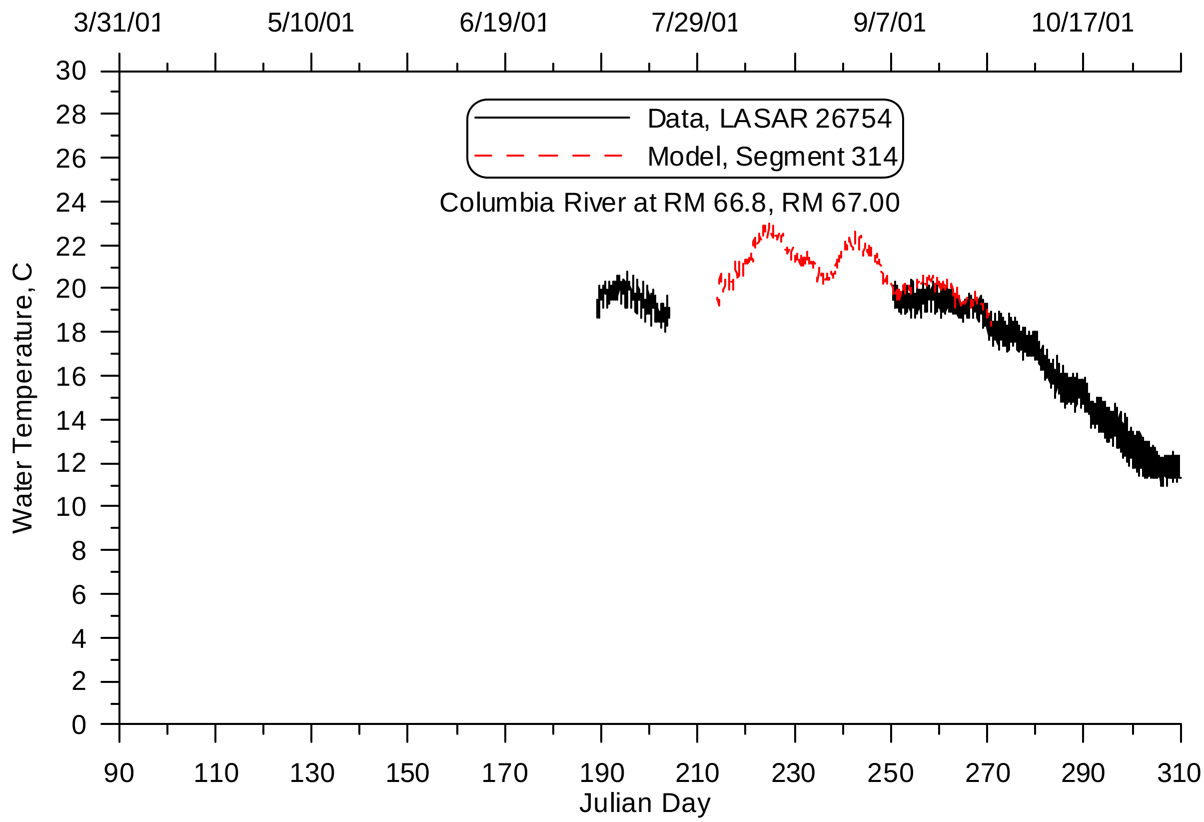

Figure 28: Columbia River at RM 66.8 model-data continuous temperature comparison, 2001

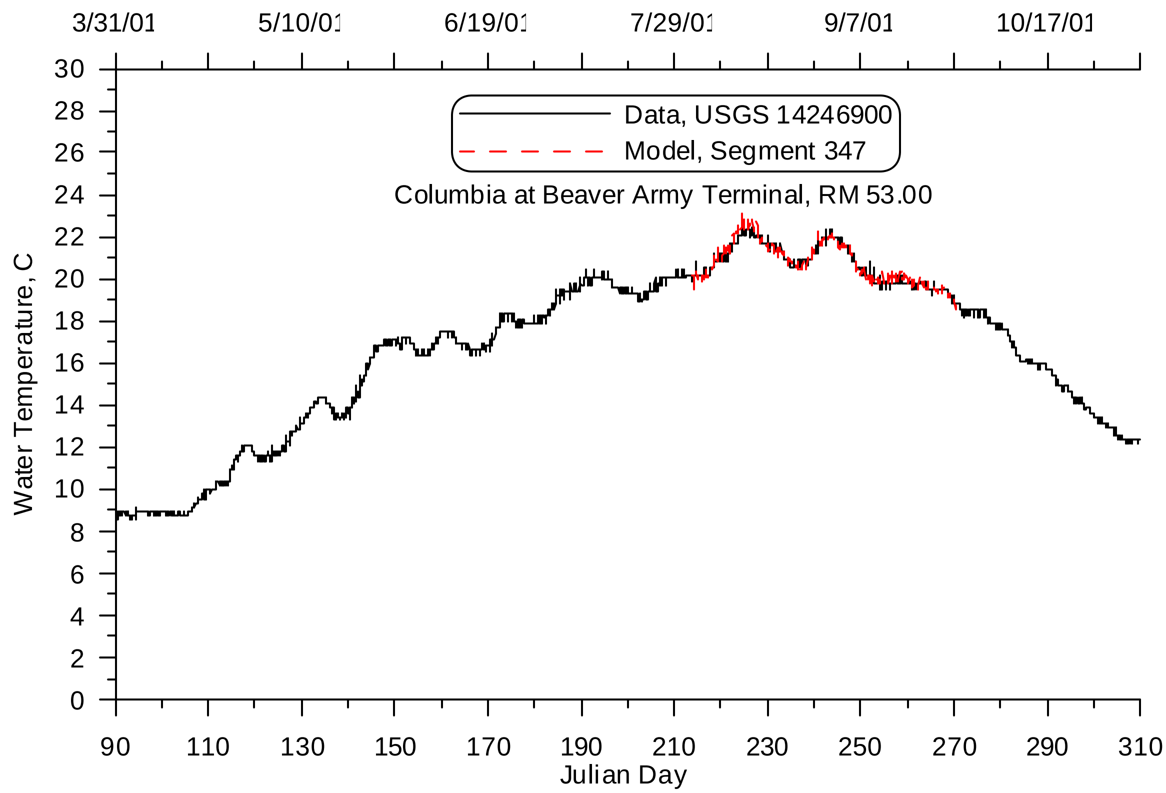

Figure 29: Columbia River at Beaver Army Terminal model-data continuous temperature comparison, 2001

Year 2002

Continuous water temperature error statistics for the 2002 Lower Willamette River model are listed in Table 9. Plots of continuous temperature predictions and data were shown in Figure 30 through Figure 51. The figures show there is good model-data agreement both on diurnal cycles and in matching the 10 to 14 day weather patterns seen in the water temperature data. Similarly to the year 2001, error statistics were less than 0.80 ^{o}C. Again, since hydrodynamics were calibrated and the model bathymetry, meteorological data, and inflow data well described, calibration of temperature was fairly straight forward and required setting the light extinction to a value of 0.6 m^{-1}.

Table 9: Lower Willamette River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
LASAR 26745 Shallow	20.75	33	3370	0.26	0.41	0.52
LASAR 26745 Deep	20.75	33	3370	0.19	0.36	0.45
LASAR 28506 Shallow	18.83	45	3351	0.27	0.40	0.49
LASAR 28506 Deep	18.83	45	3351	-0.14	0.42	0.48
LASAR 28507 Shallow	18.75	46	3351	0.27	0.40	0.48
LASAR 28507 Deep	18.75	46	3351	-0.13	0.38	0.44
LASAR 28508 Shallow	18.59	48	3351	0.33	0.43	0.53
LASAR 28508 Deep	18.59	48	3351	-0.04	0.36	0.41

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 29747	17.38	52	2945	0.20	0.35	0.43
LASAR 29747 QA set	17.38	52	1995	0.14	0.30	0.38
USGS 14211720	12.70	66	8780	0.10	0.34	0.43
LASAR 28765 Shallow	7.14	83	2402	-0.14	0.27	0.34
LASAR 28765 Deep	7.14	83	3351	-0.01	0.24	0.30
LASAR 29746 Shallow	3.20	91	3351	-0.02	0.33	0.44
LASAR 29746 Deep	3.20	91	3351	0.17	0.35	0.46
USGS 453630122021400	140.40	134	4390	0.02	0.05	0.09
USGS 453439122223900	121.75	187	4390	-0.03	0.14	0.24
LASAR 26747 Shallow	85.50	271	5296	-0.66	0.67	0.78
LASAR 26747 Deep	85.50	271	5296	-0.16	0.27	0.34
LASAR 26754 Shallow	67.00	314	5299	0.45	0.49	0.58
LASAR 26754 Deep	67.00	314	5299	0.40	0.45	0.54
USGS 14246900	53.00	347	17557	0.04	0.17	0.29

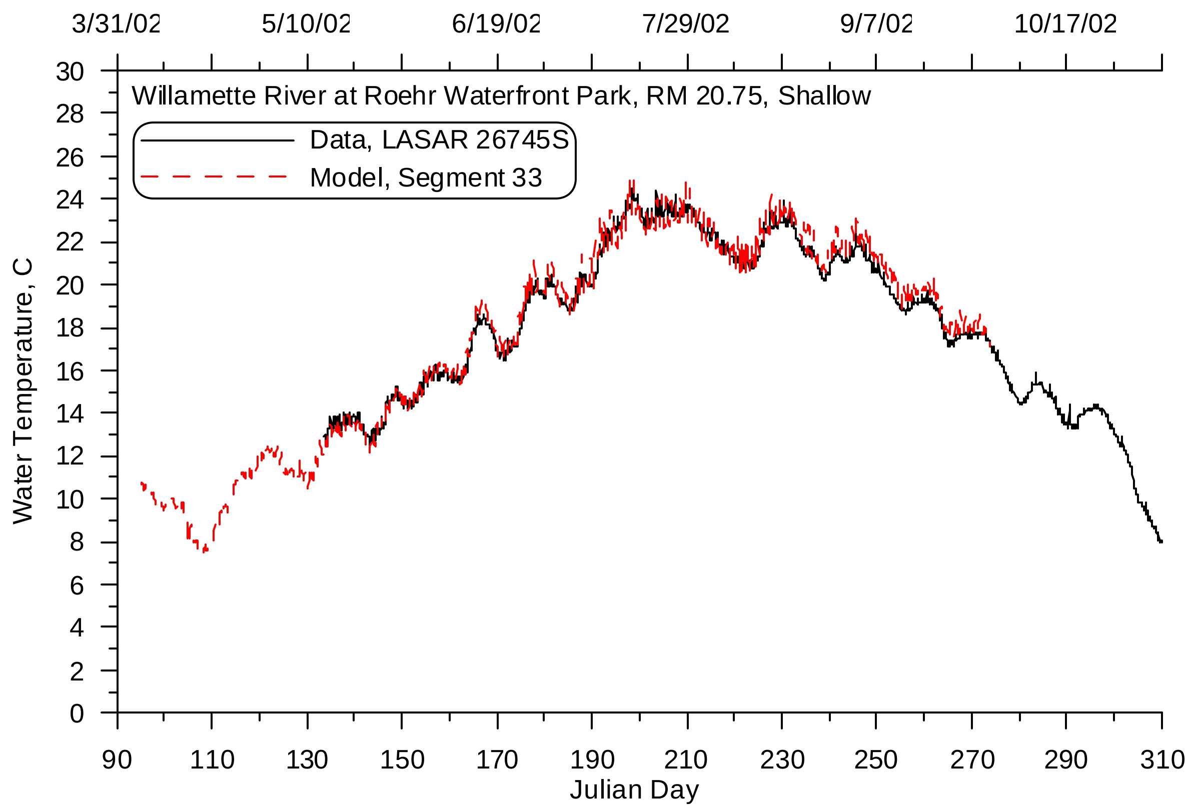

Figure 30: Willamette River at Roehr Waterfront Park (shallow) model-data continuous temperature comparison, 2002

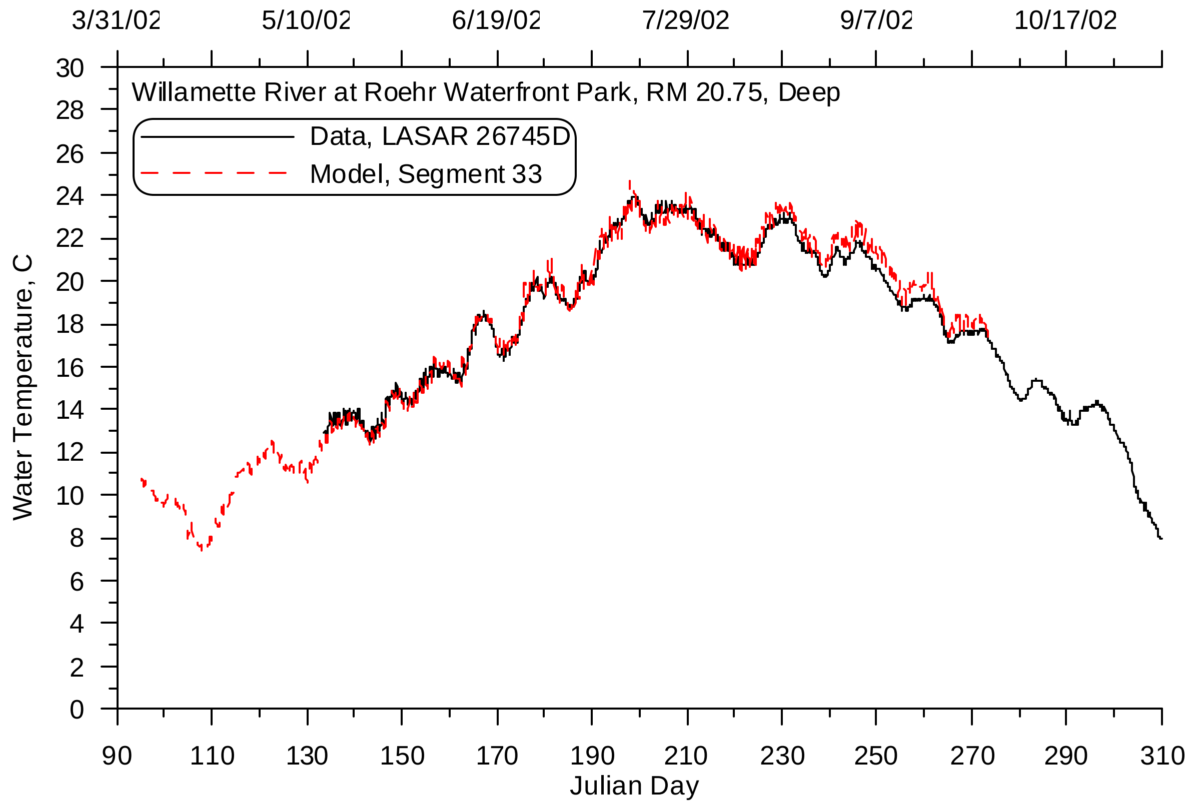

Figure 31: Willamette River at Roehr Waterfront Park (deep) model-data continuous temperature comparison, 2002

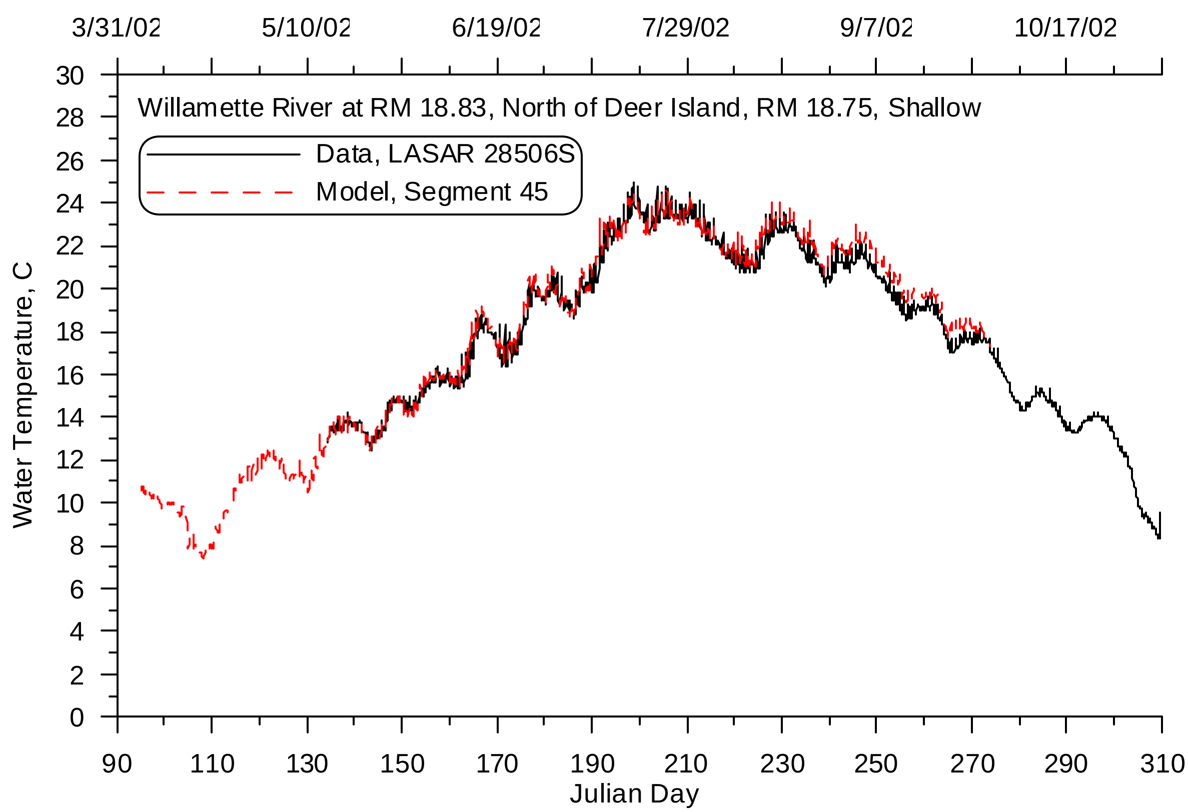

Figure 32: Willamette River north of Deer Island (shallow) model-data continuous temperature comparison, 2002

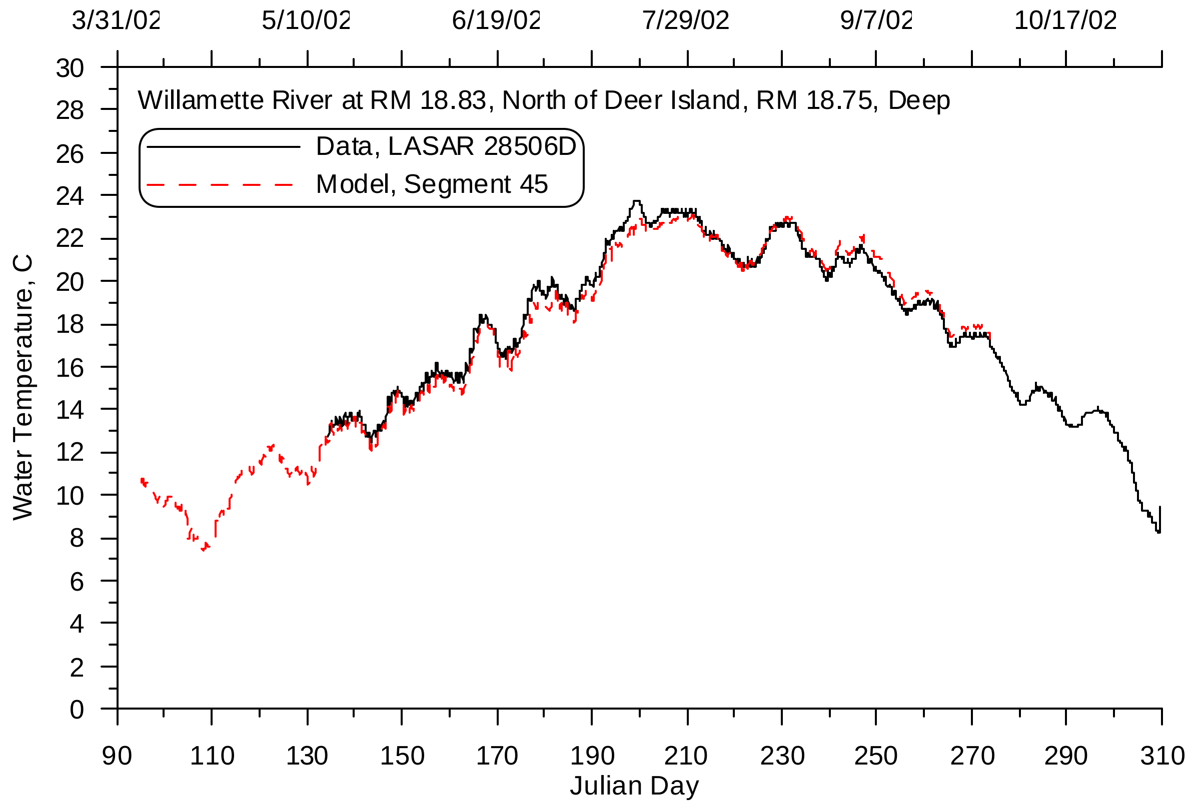

Figure 33: Willamette River north of Deer Island (deep) model-data continuous temperature comparison, 2002

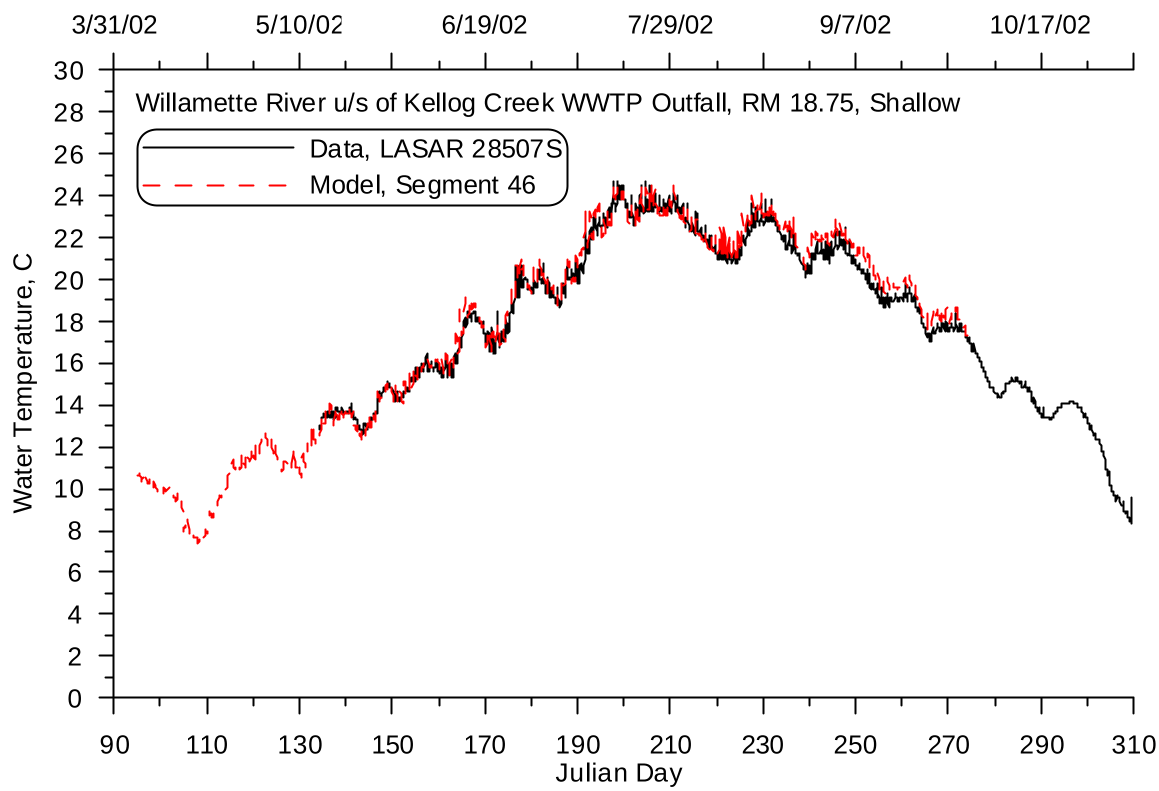

Figure 34: Willamette River upstream of Kellog Creek WWTP outfall (shallow) model-data continuous temperature comparison, 2002

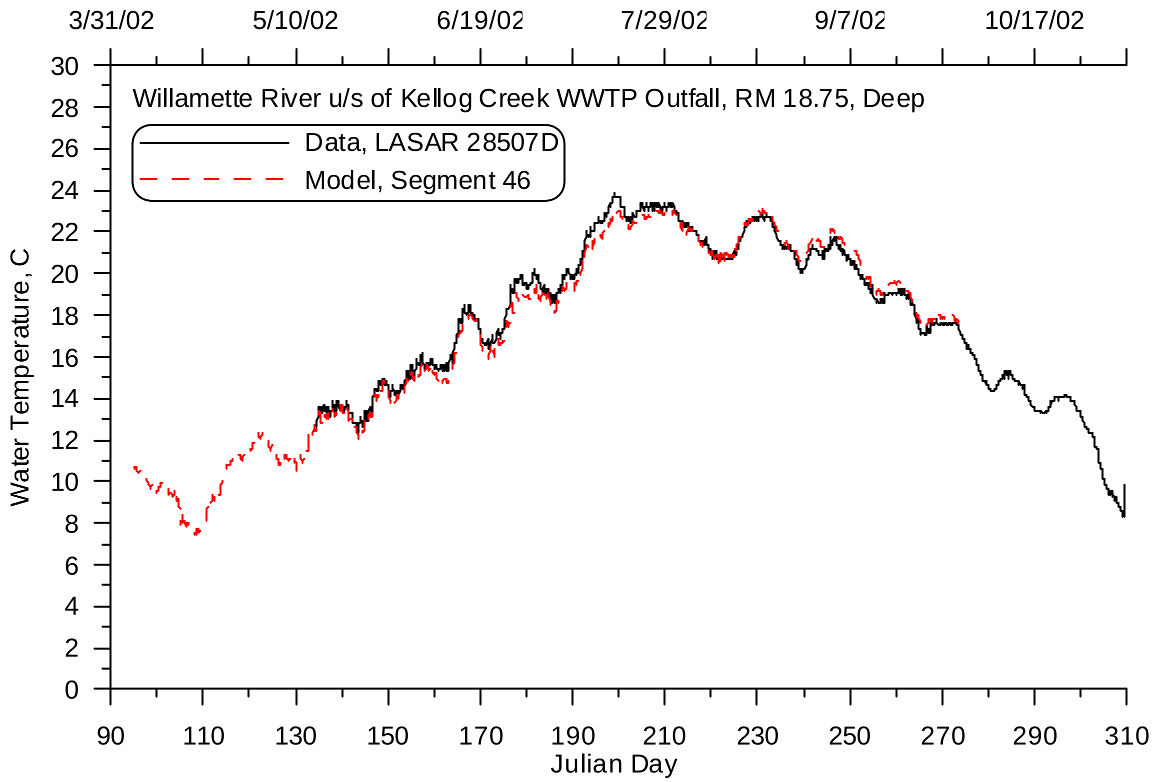

Figure 35: Willamette River upstream of Kellog Creek WWTP outfall (deep) model-data continuous temperature comparison, 2002

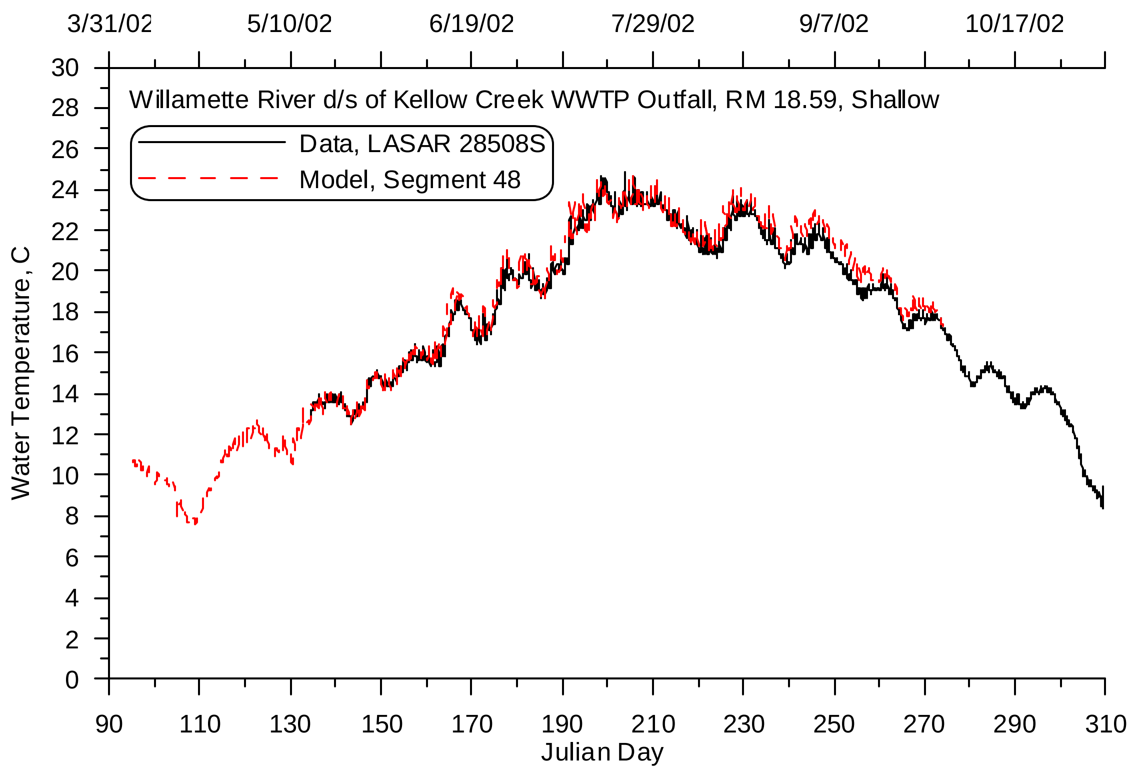

Figure 36: Willamette River downstream of Kellog Creek WWTP outfall (shallow) model-data continuous temperature comparison, 2002

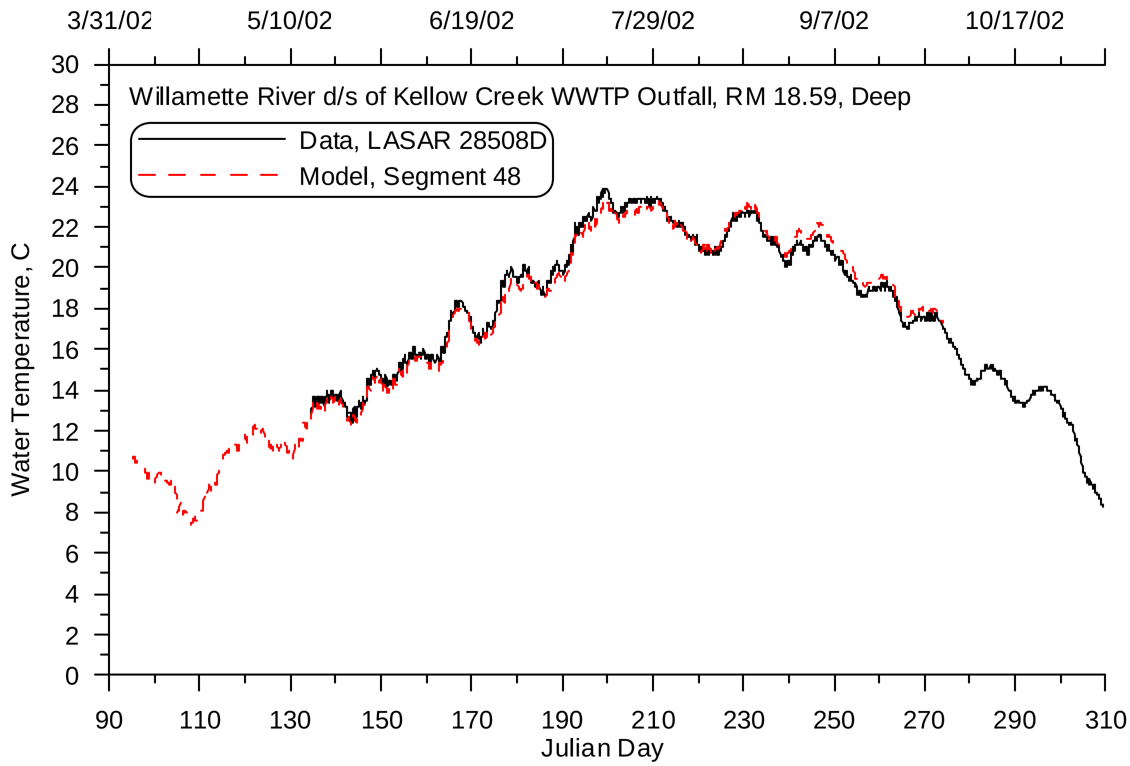

Figure 37: Willamette River downstream of Kellog Creek WWTP outfall (deep) model-data continuous temperature comparison, 2002

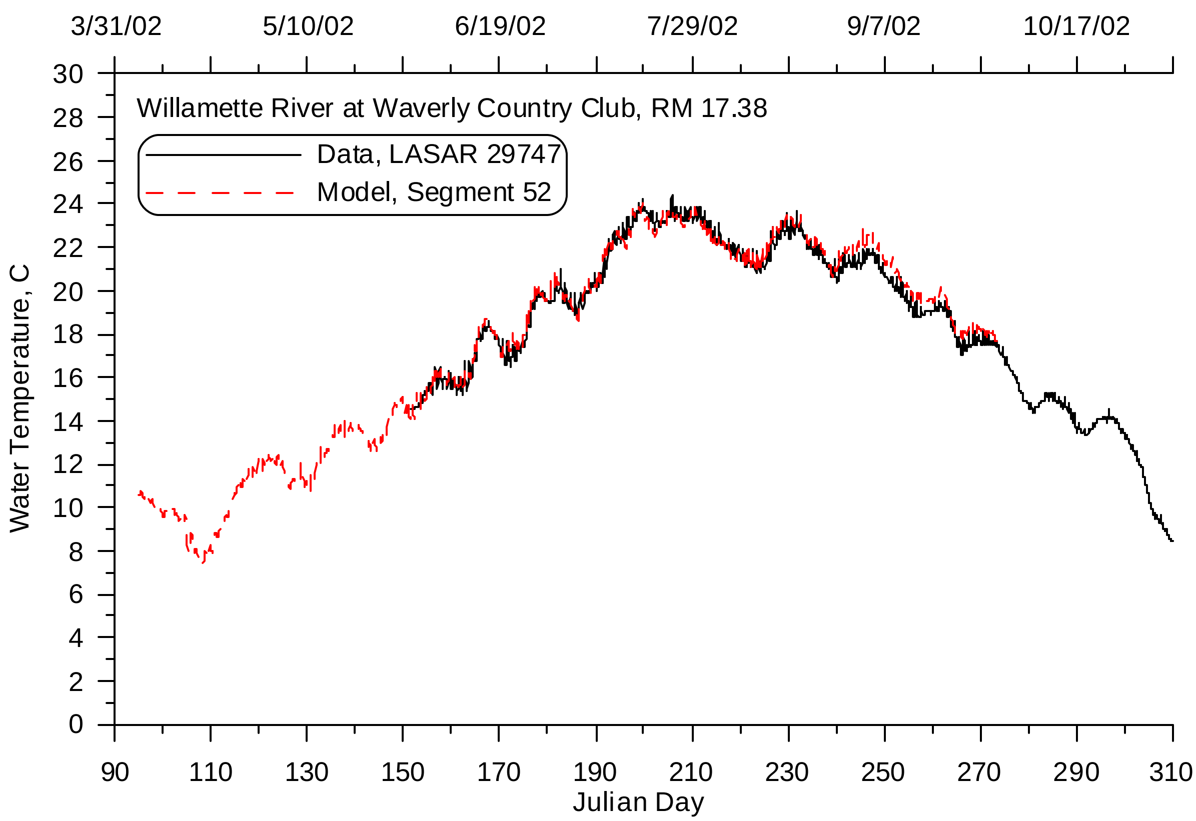

Figure 38: Willamette River at Waverly Country Club model-data continuous temperature comparison, 2002

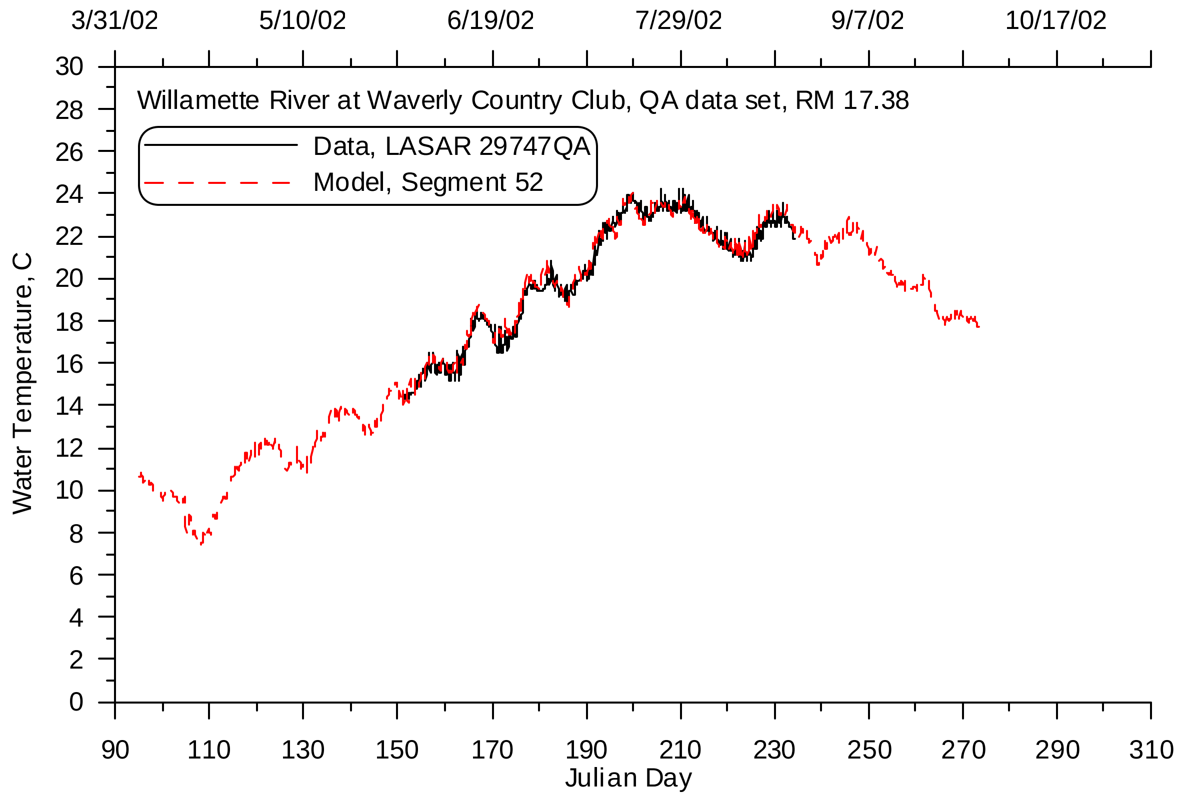

Figure 39: Willamette River at Waverly Country Club (QA data set) model-data continuous temperature comparison, 2002

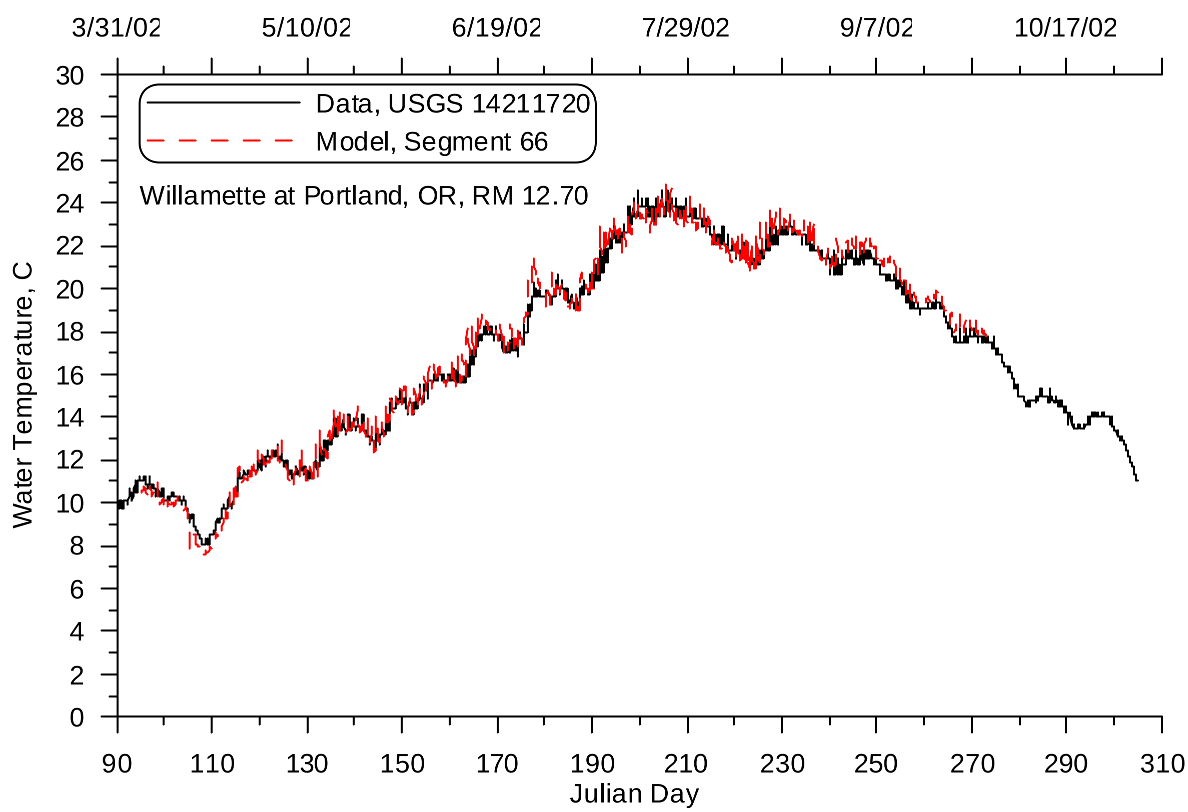

Figure 40: Willamette River at Portland model-data continuous temperature comparison, 2002

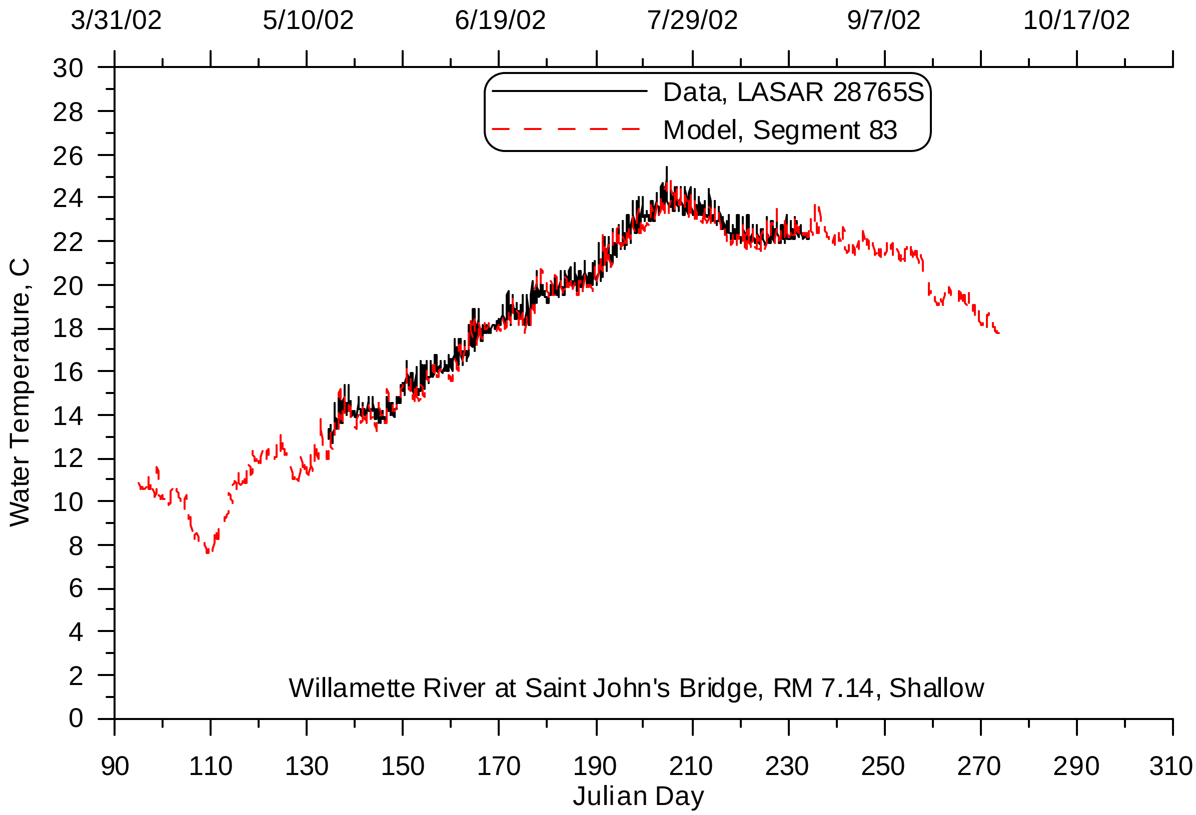

Figure 41: Willamette River at St. Johns Bridge (shallow) model-data continuous temperature comparison, 2002

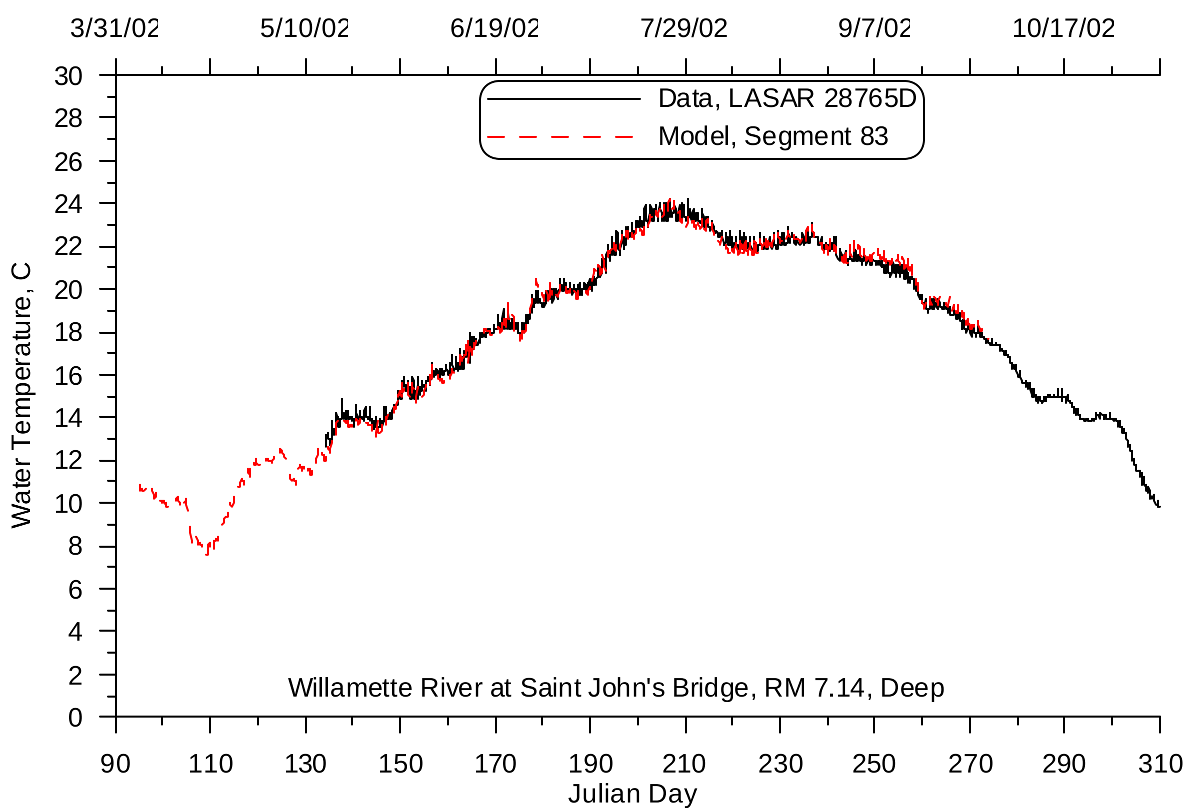

Figure 42: Willamette River at St. Johns Bridge (deep) model-data continuous temperature comparison, 2002

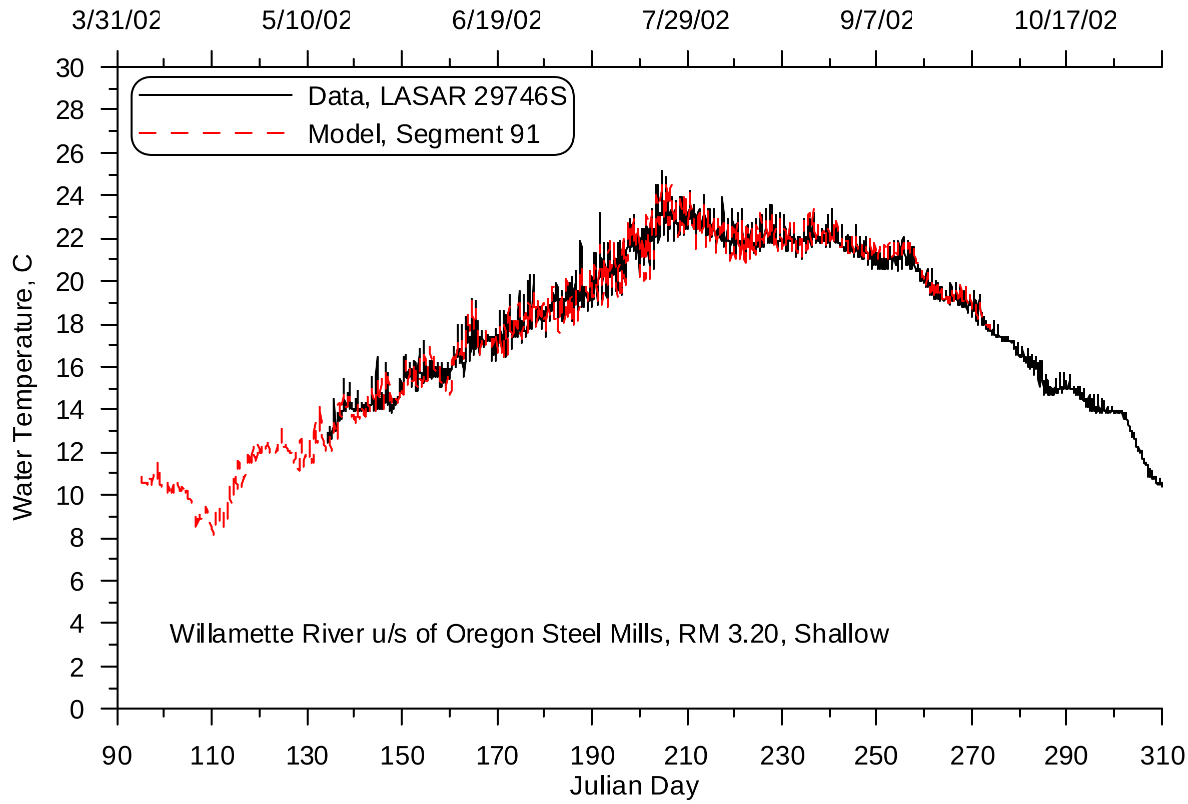

Figure 43: Willamette River upstream of Oregon Steel Mills (shallow) model-data continuous temperature comparison, 2002

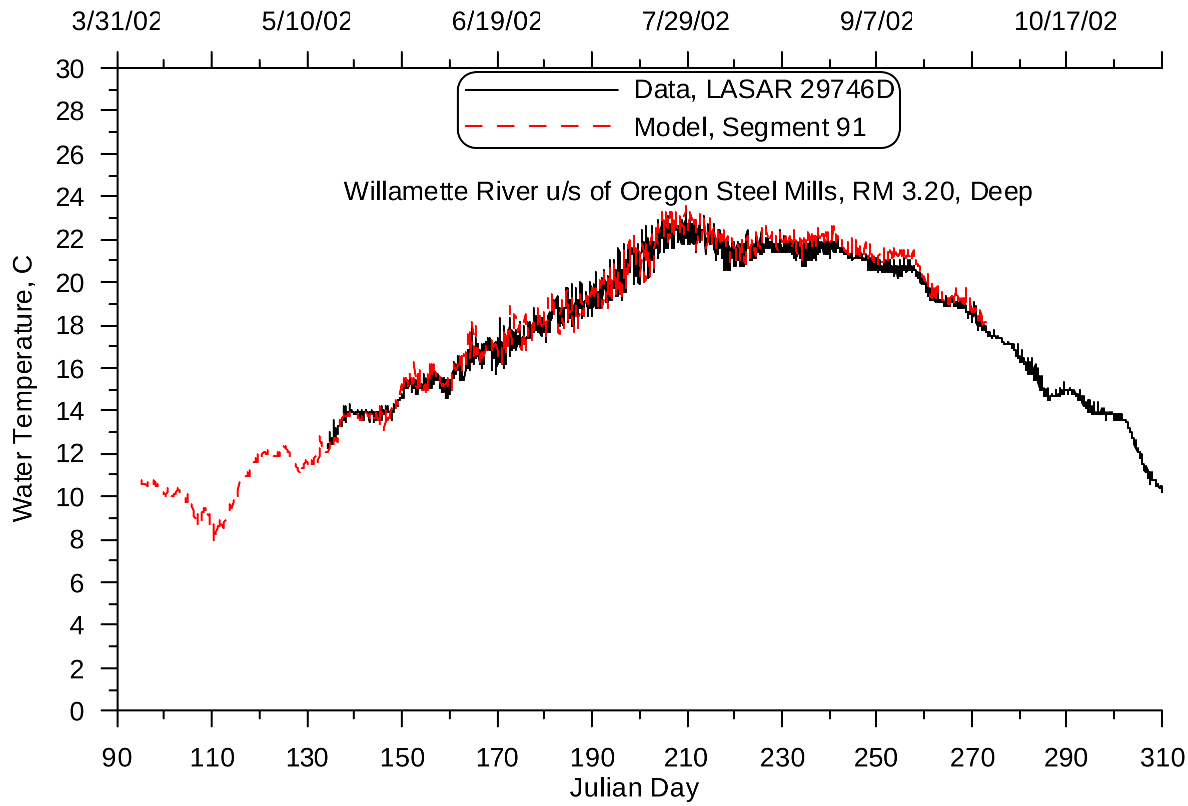

Figure 44: Willamette River upstream of Oregon Steel Mills (deep) model-data continuous temperature comparison, 2002

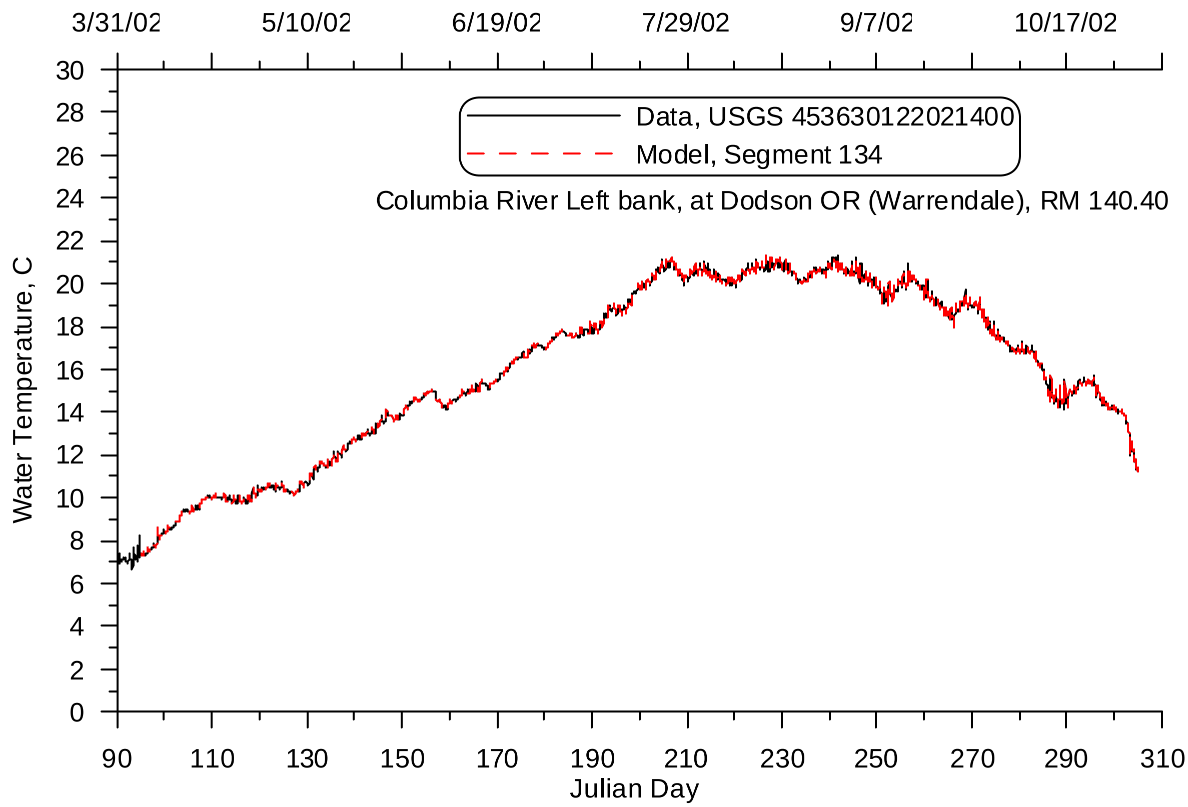

Figure 45: Columbia River left bank at Dodson, OR model-data continuous temperature comparison, 2002

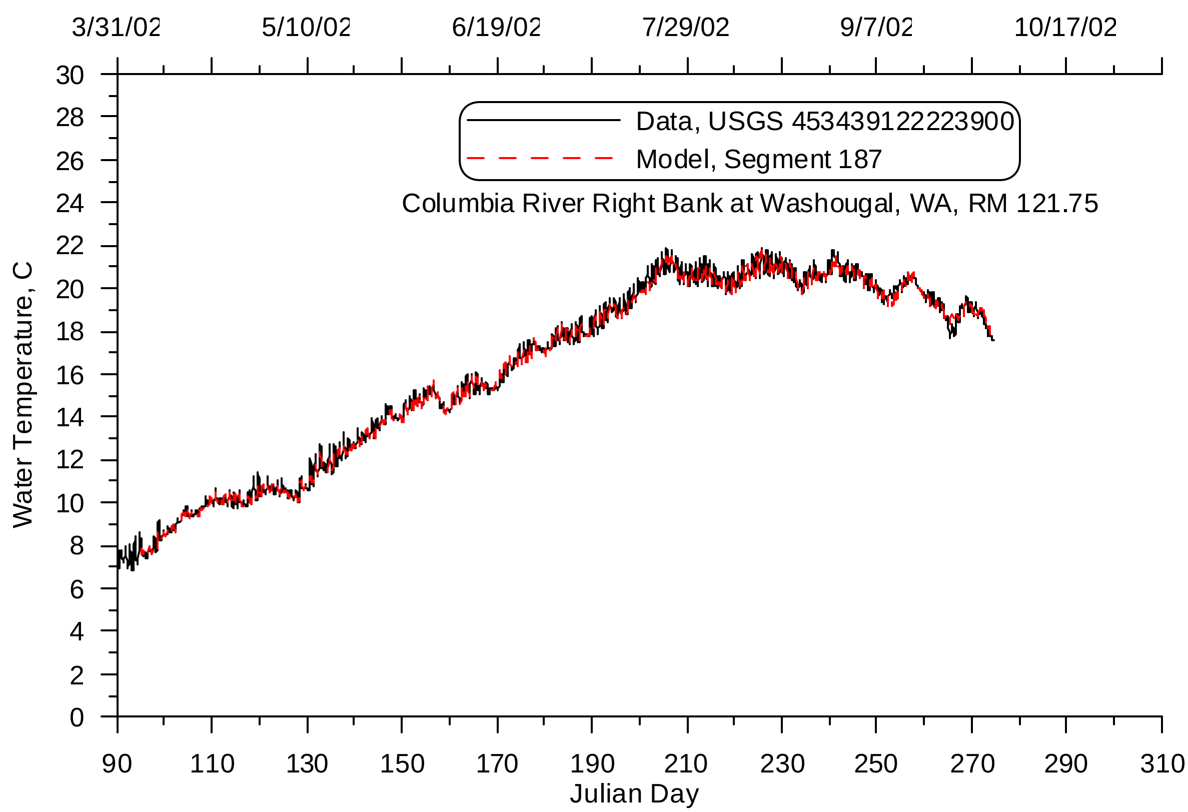

Figure 46: Columbia River at Washougal, WA model-data continuous temperature comparison, 2002

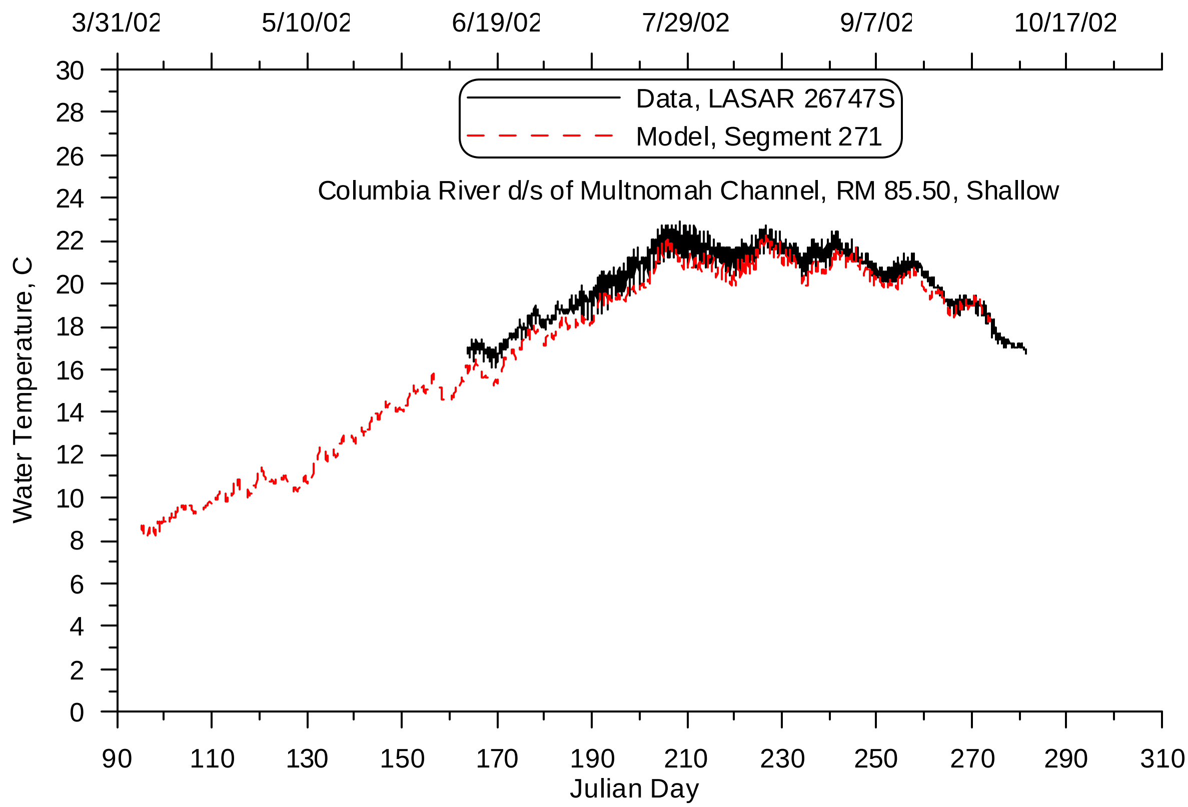

Figure 47: Columbia River downstream of Multnomah Channel (shallow) model-data continuous temperature comparison, 2002

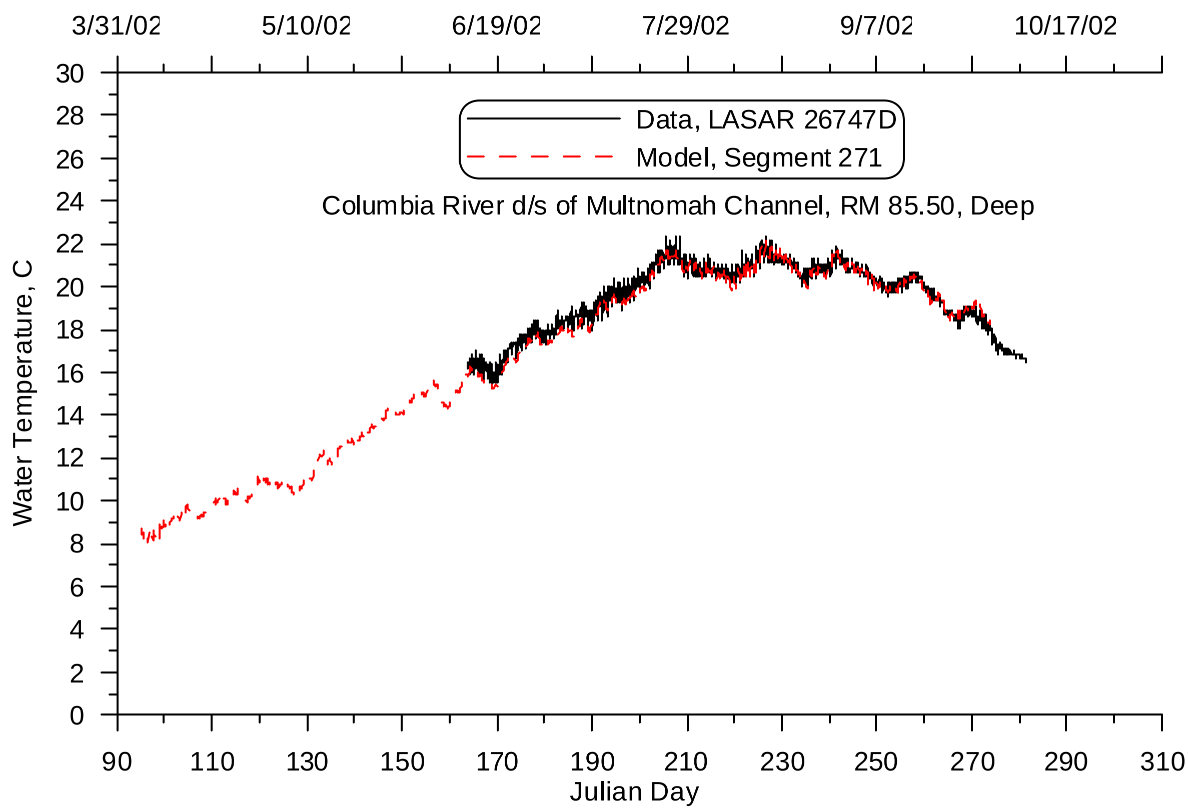

Figure 48: Columbia River downstream of Multnomah Channel (deep) model-data continuous temperature comparison, 2002

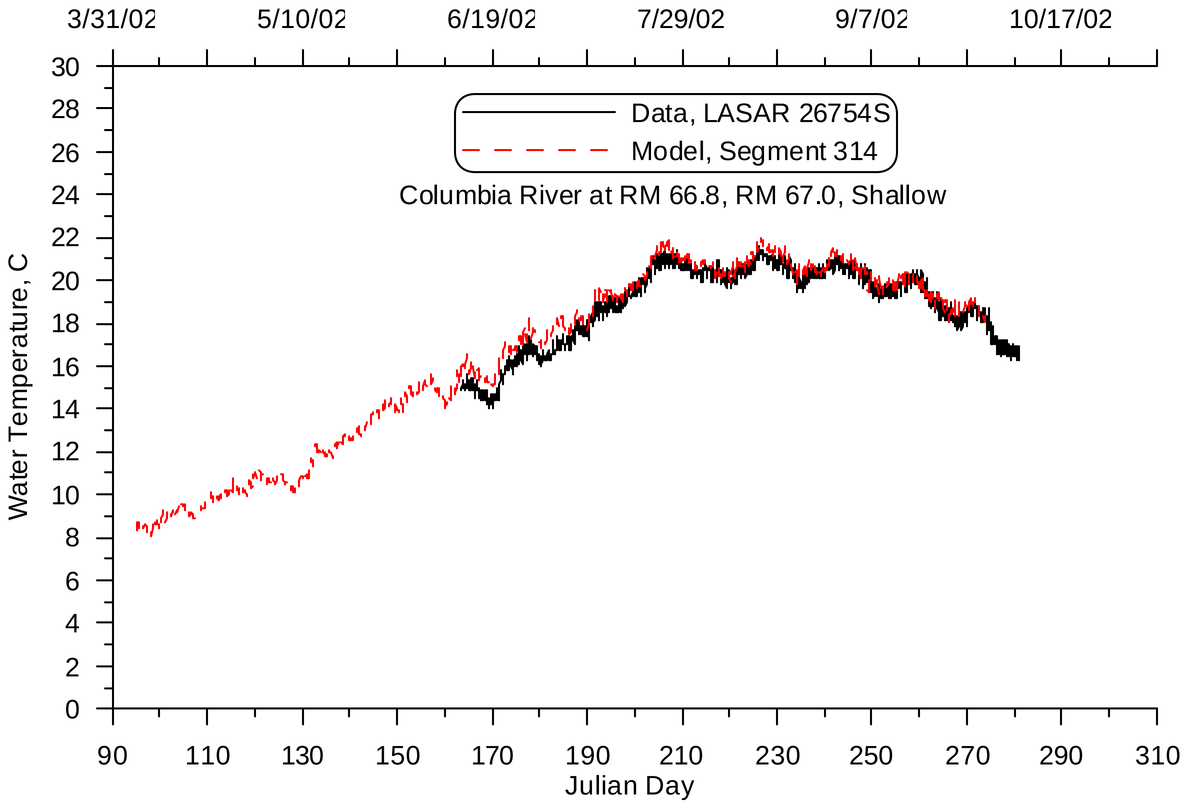

Figure 49: Columbia River at RM 66.8 (shallow) model-data continuous temperature comparison, 2002

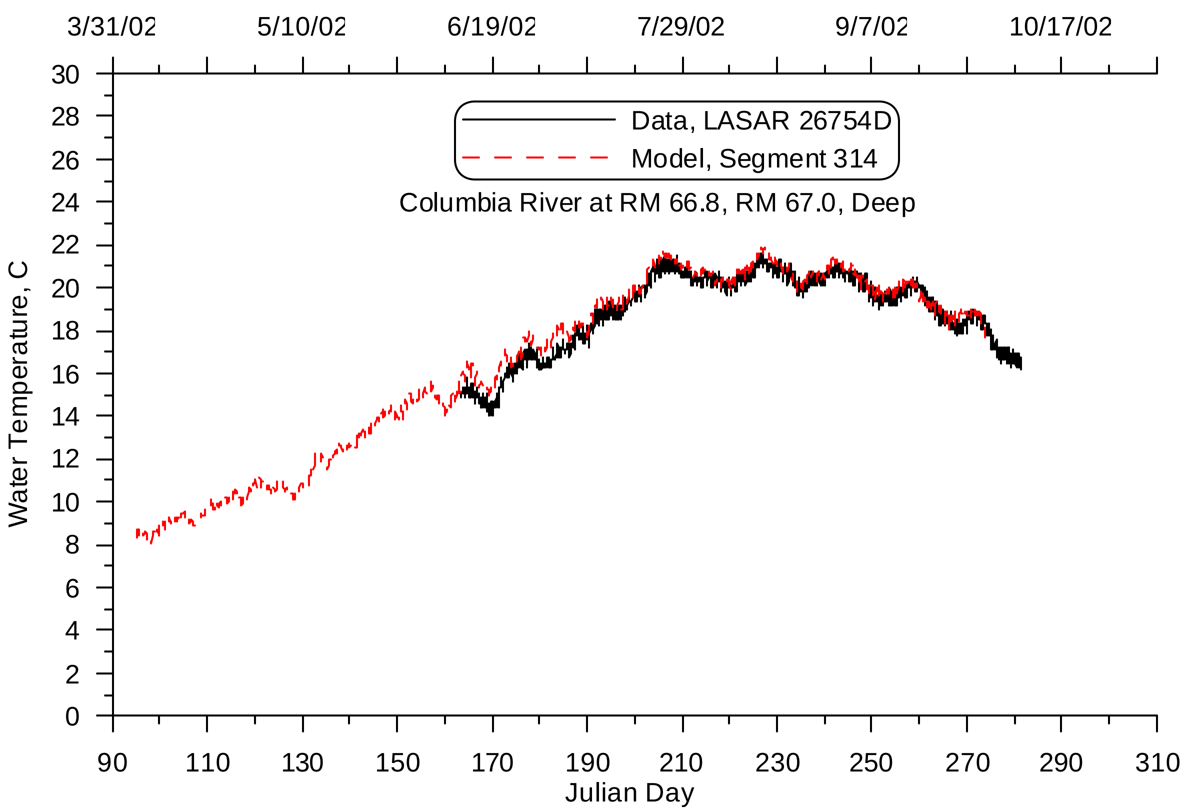

Figure 50: Columbia River at RM 66.8 (deep) model-data continuous temperature comparison, 2002

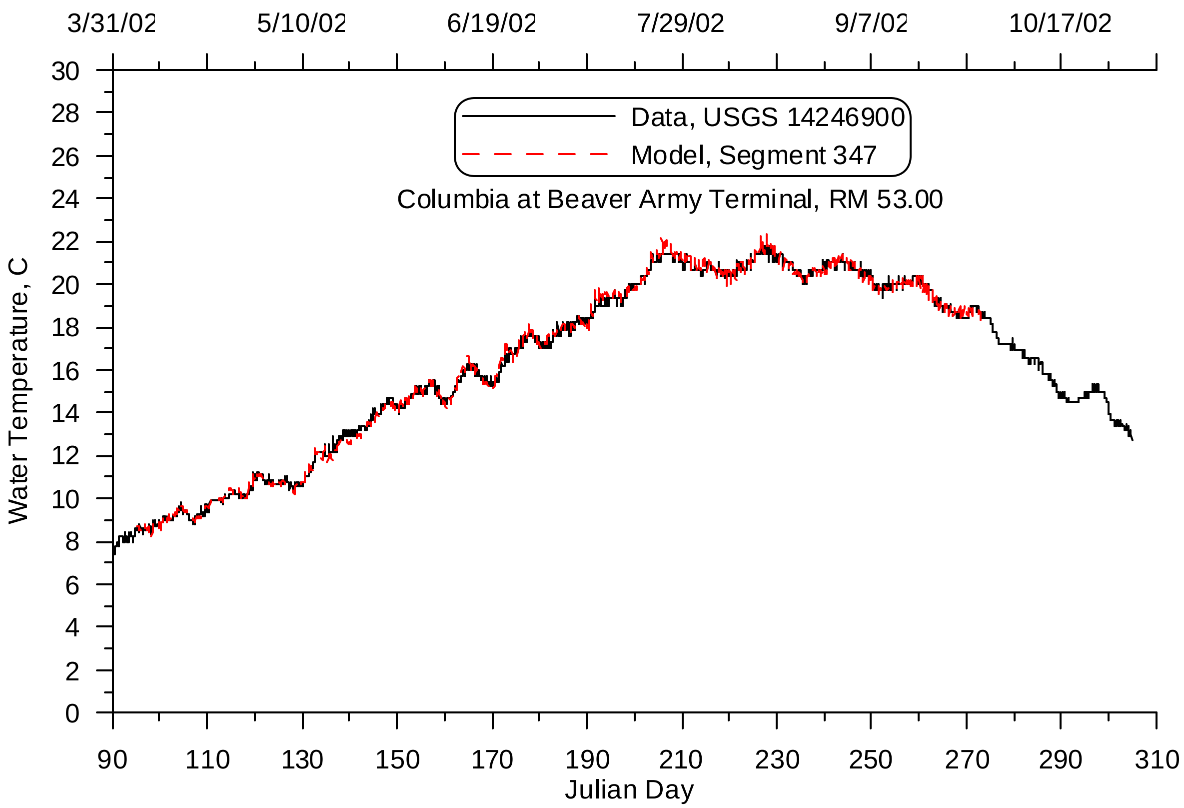

Figure 51: Columbia River at Beaver Army Terminal model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

Year 2001

Model-data error statistics the 2001 model year daily maximum temperatures are shown in Table 10. Figure 52 through Figure 63 show plots comparing daily maximum water temperature with data for the year 2001 Lower Willamette River model. The figures show the model is doing well in representing the daily maximum temperatures in the Lower Willamette River and the Columbia River Model-data error statistics for daily maximum temperature are less than 0.5 ^{o}C.

Table 10: Lower Willamette River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
PGE_2590 A	26.24	2	64	0.03	0.33	0.40
PGE_2590 B	26.24	2	64	-0.16	0.36	0.44
LASAR 26745 Shallow	20.75	33	64	0.03	0.37	0.44
LASAR 26745 Deep	20.75	33	64	0.09	0.37	0.43
LASAR 26760	11.10	107	5	-0.24	0.29	0.37
USGS4 53651122022200	140.40	134	64	-0.23	0.24	0.29

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 453630122021400	140.40	134	54	0.08	0.08	0.10
USGS 453439122223900	121.75	187	54	-0.11	0.13	0.16
USGS 14129400 LASAR 26752	121.50	188	64	-0.17	0.20	0.24
LASAR 26747	85.50	271	5	-0.42	0.42	0.46
LASAR 26754	67.00	314	22	0.12	0.20	0.26
USGS 14246900	53.00	347	64	0.10	0.20	0.27

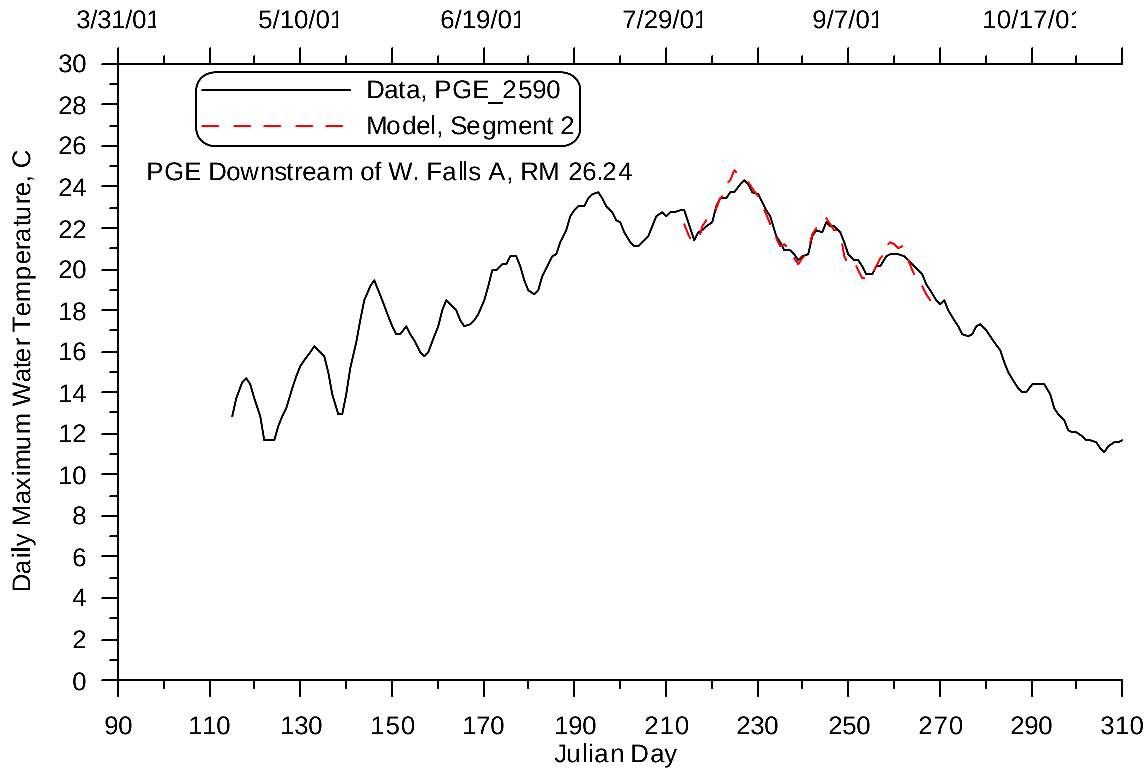

Figure 52: Willamette River downstream of the Willamette Falls site A model-data daily maximum temperature comparison, 2001

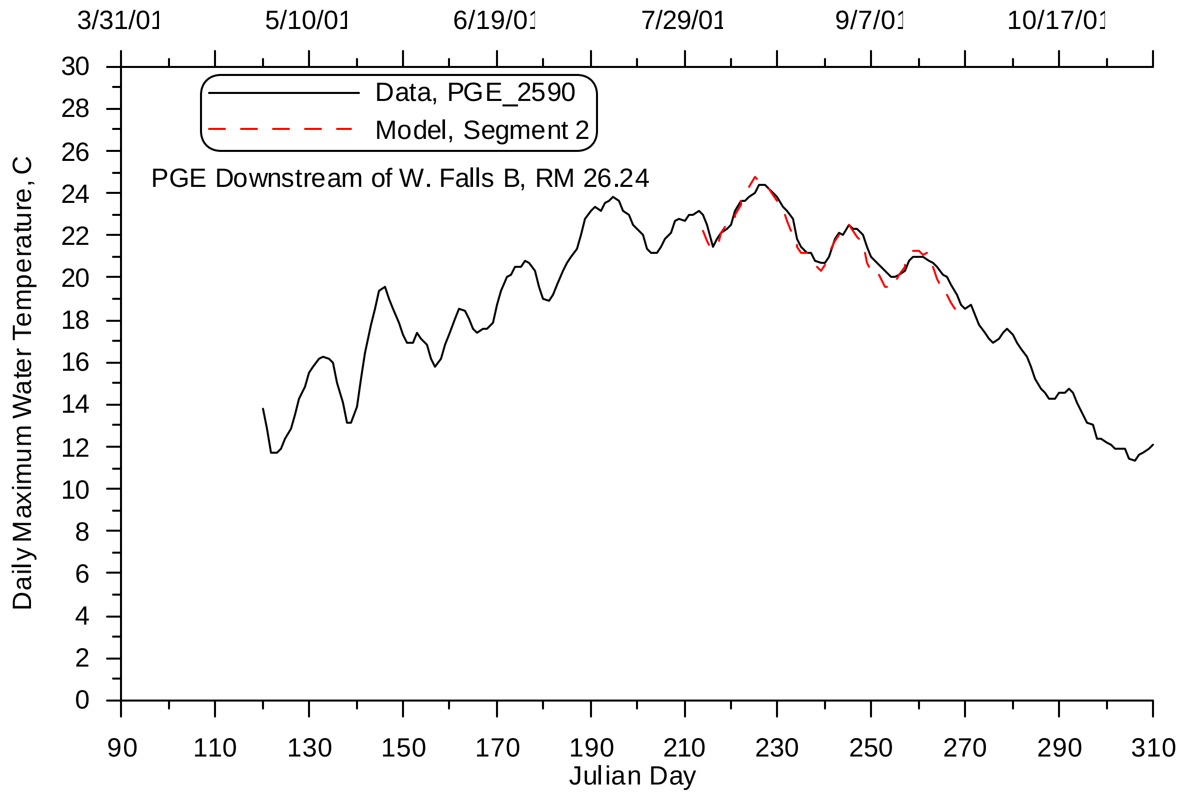

Figure 53: Willamette River downstream of the Willamette Falls site B model-data daily maximum temperature comparison, 2001

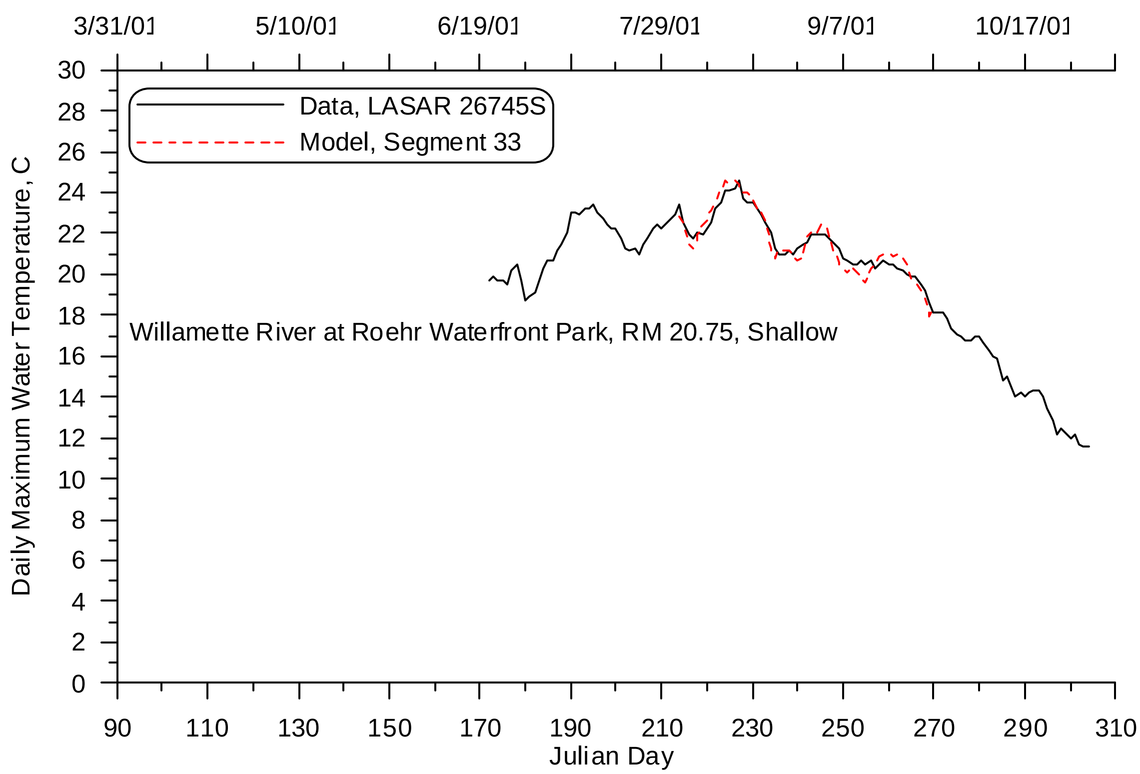

Figure 54: Willamette River at Roehr Waterfront Park (shallow) model-data daily maximum temperature comparison, 2001

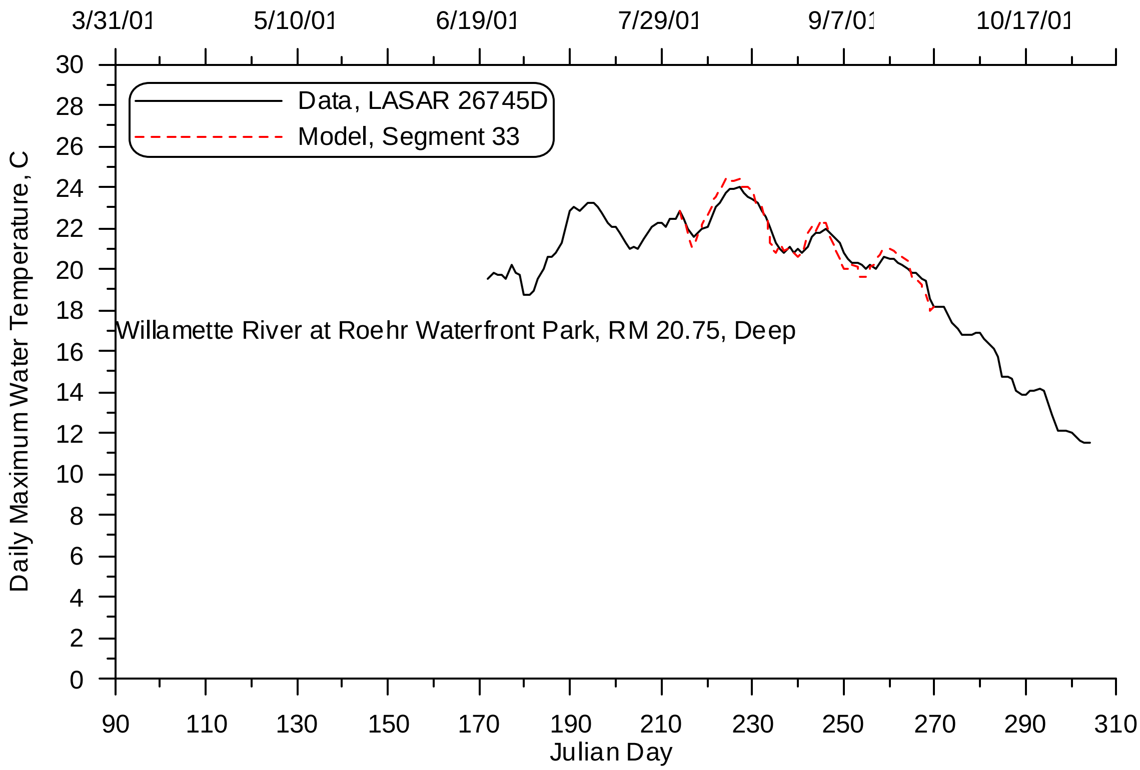

Figure 55: Willamette River at Roehr Waterfront Park (deep) model-data daily maximum temperature comparison, 2001

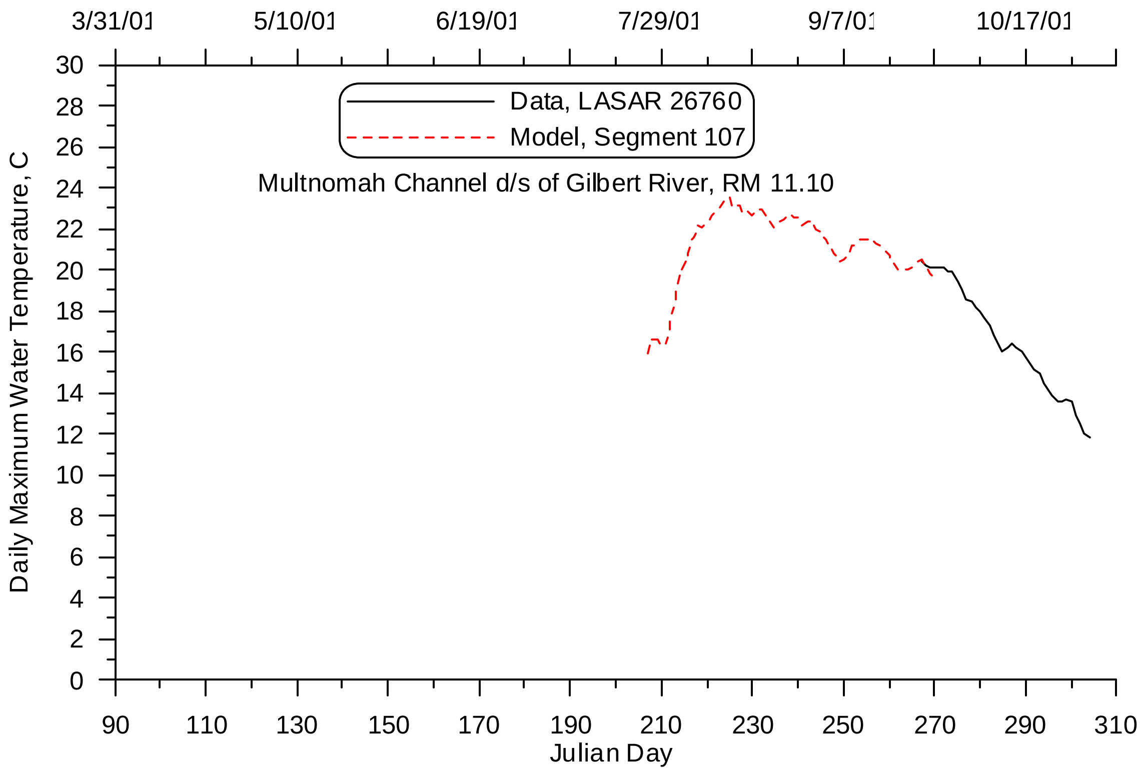

Figure 56: Multnomah Channel downstream of Gilbert River model-data daily maximum temperature comparison, 2001

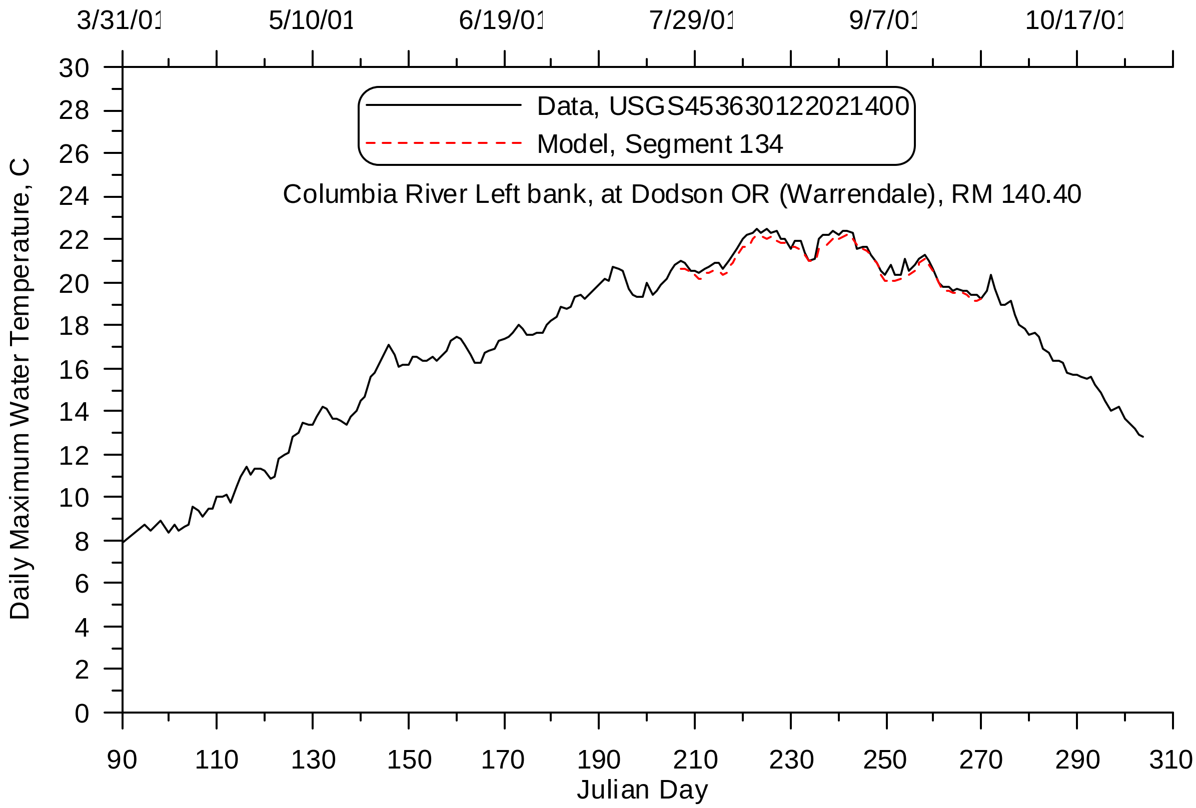

Figure 57: Columbia River Left Bank at Dodson, OR model-data daily maximum temperature comparison, 2001

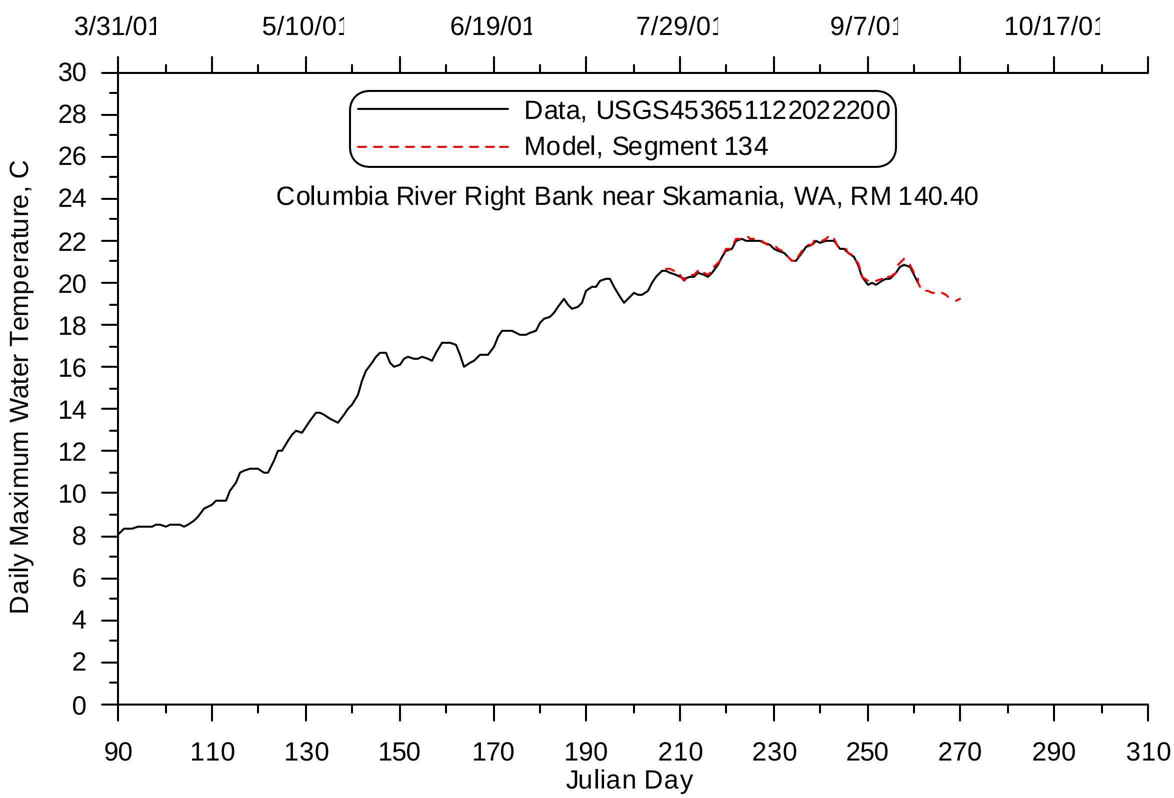

Figure 58: Columbia River Right Bank near Skamania, WA model-data daily maximum temperature comparison, 2001

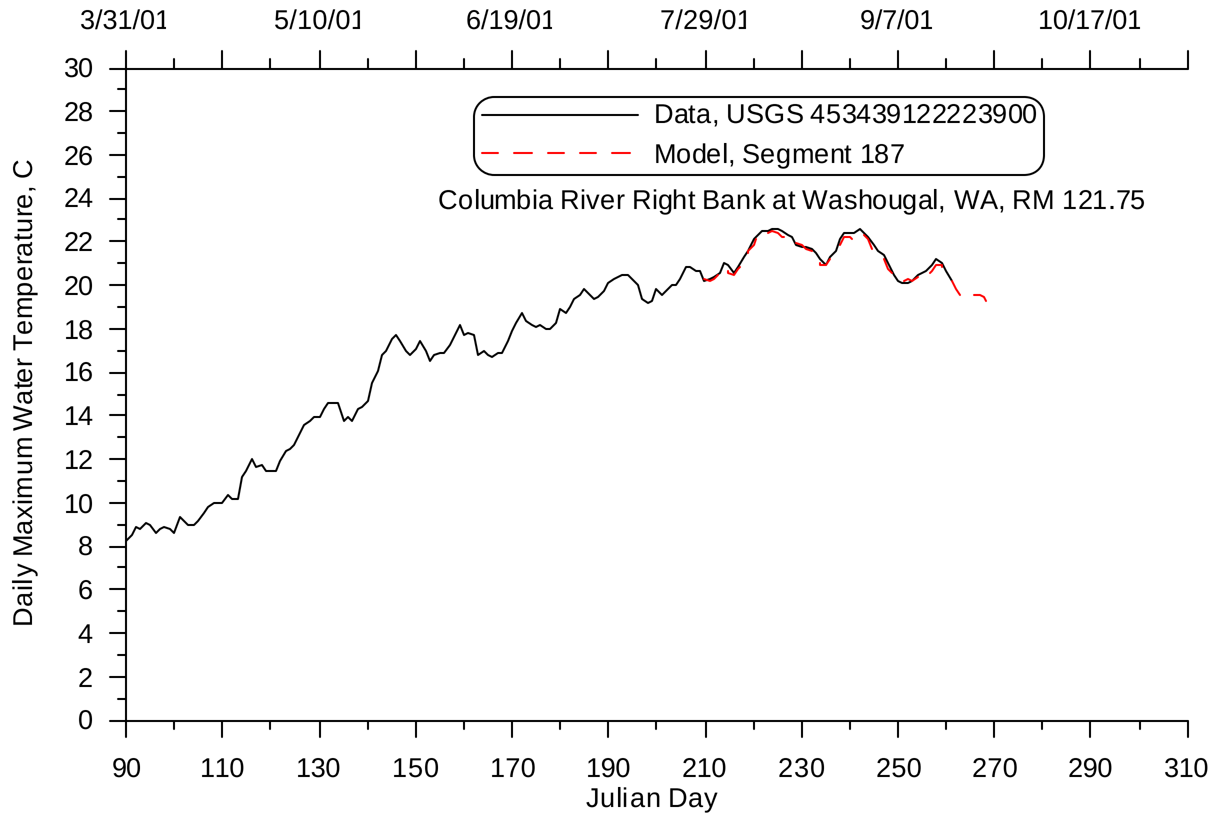

Figure 59: Columbia River at Washougal, WA model-data daily maximum temperature comparison, 2001

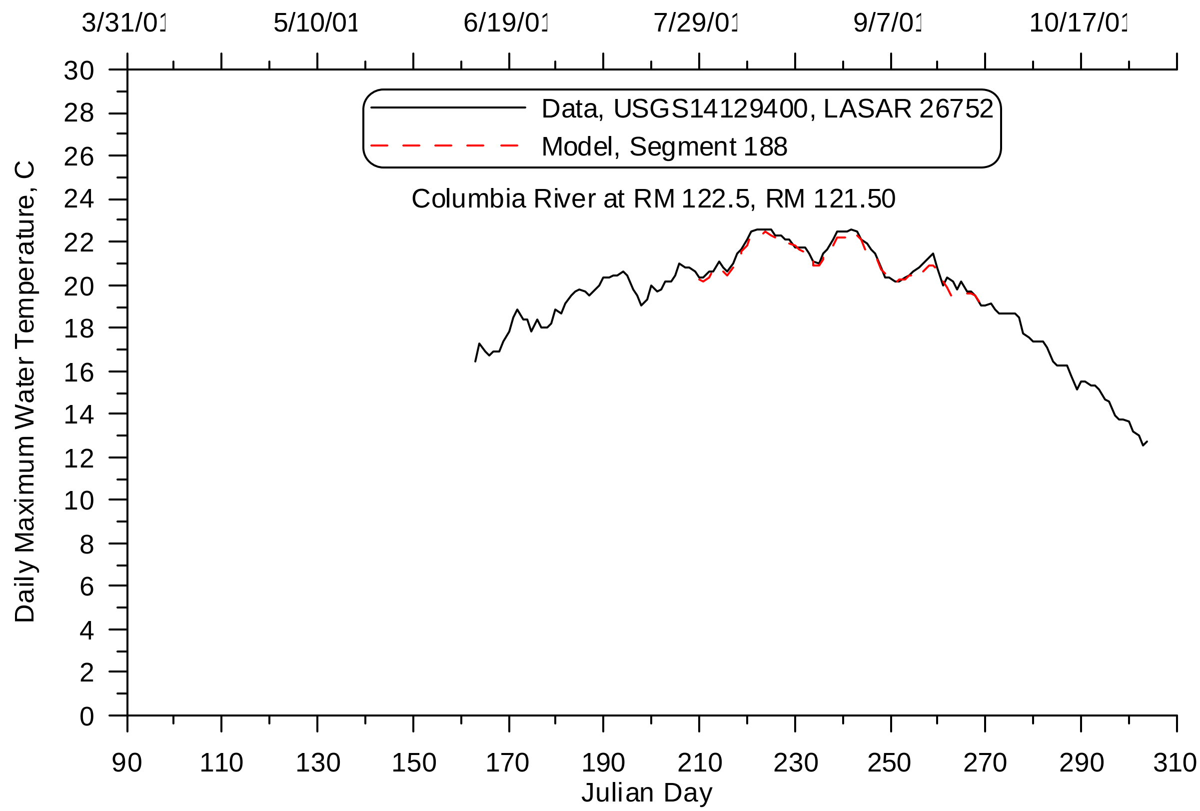

Figure 60: Columbia River at RM 122.5 model-data daily maximum temperature comparison, 2001

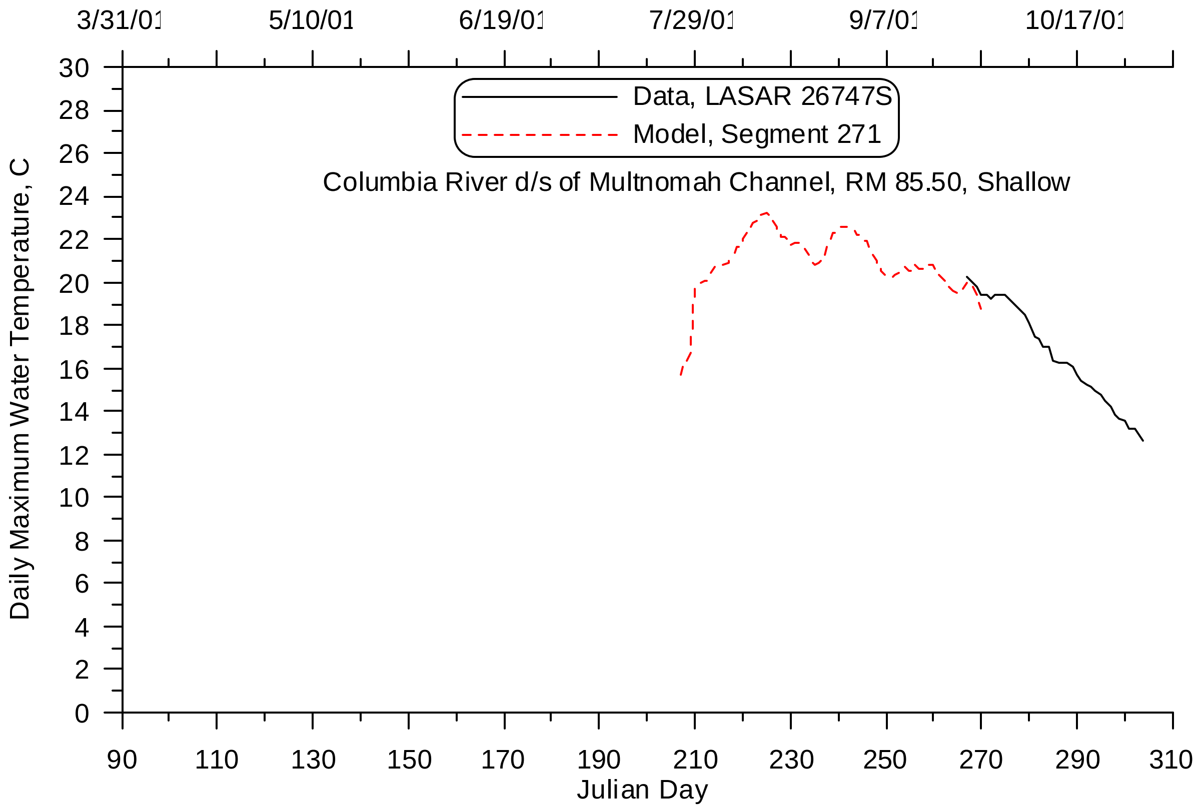

Figure 61: Columbia River d/s Multnomah Channel model-data daily maximum temperature comparison, 2001

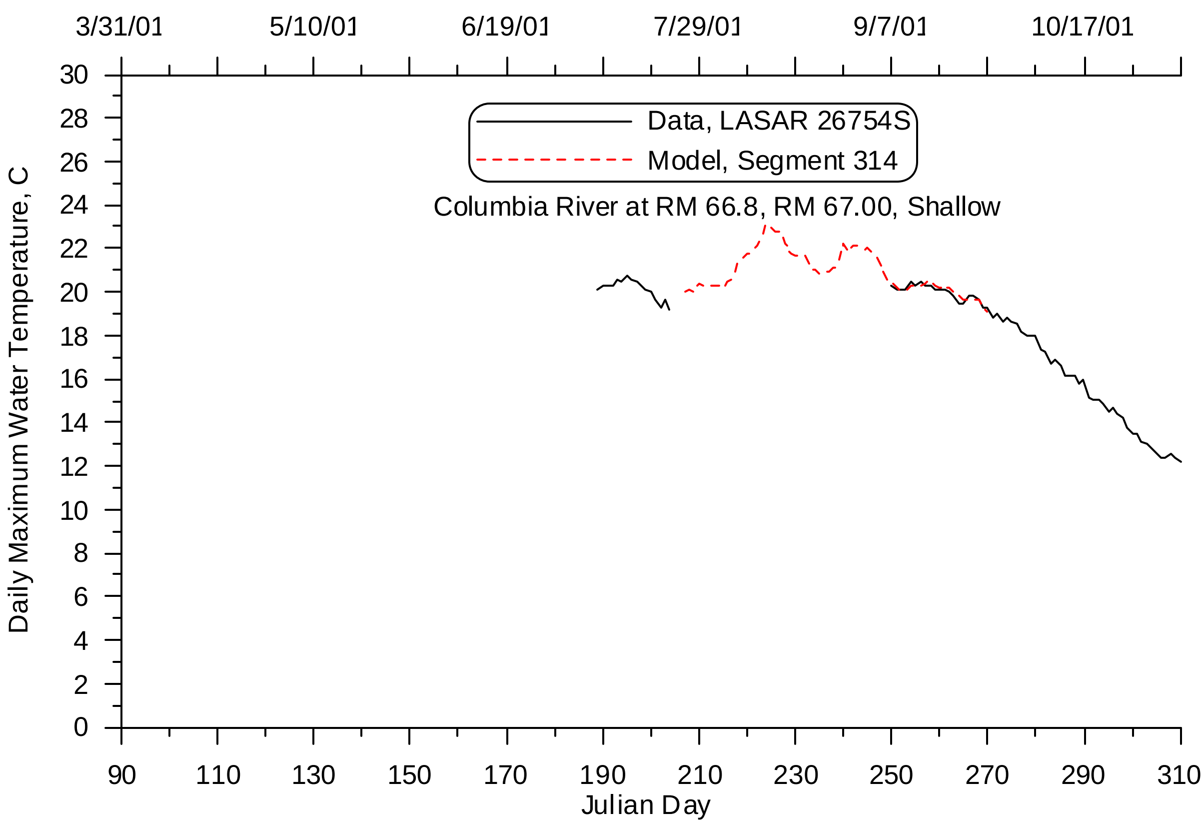

Figure 62: Columbia River at RM 66.8 model-data daily maximum temperature comparison, 2001

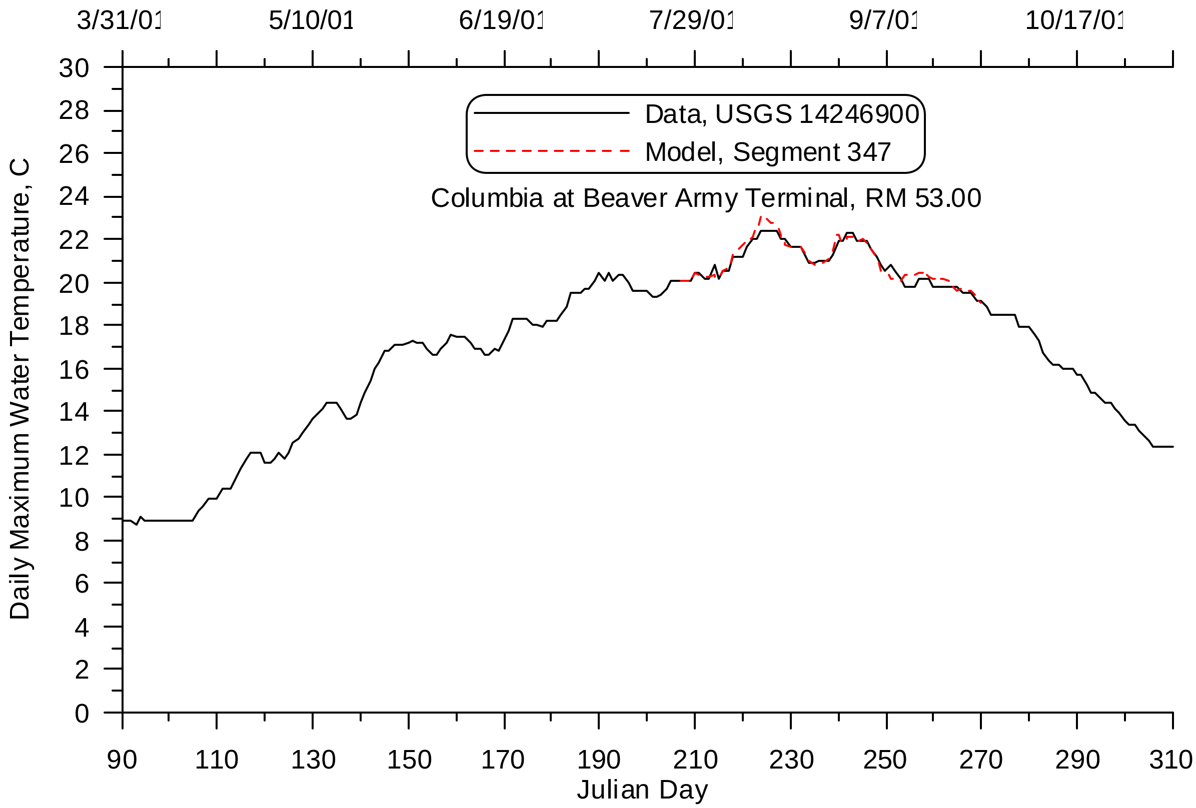

Figure 63: Columbia River at Beaver Army Terminal model-data daily maximum temperature comparison, 2001

Year 2002

Table 11 shows daily maximum water temperature model-data error statistics for the 2002 Lower Willamette River model. Plots of the daily maximum temperature and data were shown in Figure 64 through Figure 85. Similar to 2001, the model does well in representing the daily maximum temperatures and compare with data. Except for one location on the Columbia River, the model-data error statistics are below 0.6 ^{o}C.

Table 11: Lower Willamette River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
LASAR 26745 Shallow	20.75	33	142	0.43	0.49	0.59
LASAR 26745 Deep	20.75	33	142	0.39	0.48	0.58
LASAR 28506 Shallow	18.83	45	141	0.17	0.37	0.45
LASAR 28506 Deep	18.83	45	141	-0.16	0.41	0.47
LASAR 28507 Shallow	18.75	46	141	0.28	0.38	0.47
LASAR 28507 Deep	18.75	46	141	-0.15	0.39	0.44
LASAR 28508 Shallow	18.59	48	141	0.39	0.46	0.55
LASAR 28508 Deep	18.59	48	141	-0.06	0.38	0.42
LASAR 29747	17.38	52	124	0.13	0.35	0.41
LASAR 29747 QA set	17.38	52	83	0.05	0.29	0.36

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14211720	12.70	66	183	0.26	0.41	0.51
LASAR 28765 Shallow	7.14	83	100	-0.31	0.39	0.47
LASAR 28765 Deep	7.14	83	141	0.10	0.30	0.36
LASAR 29746 Shallow	3.20	91	141	-0.19	0.38	0.48
LASAR 29746 Deep	3.20	91	141	0.14	0.33	0.42
USGS 453630122021400	140.40	134	183	0.01	0.05	0.07
USGS 453439122223900	121.75	187	182	-0.16	0.20	0.25
LASAR 26747 Shallow	85.50	271	112	-0.81	0.81	0.91
LASAR 26747 Deep	85.50	271	112	-0.37	0.42	0.50
LASAR 26754 Shallow	67.00	314	112	0.36	0.39	0.47
LASAR 26754 Deep	67.00	314	112	0.27	0.31	0.40
USGS 14246900	53.00	347	183	0.07	0.18	0.30

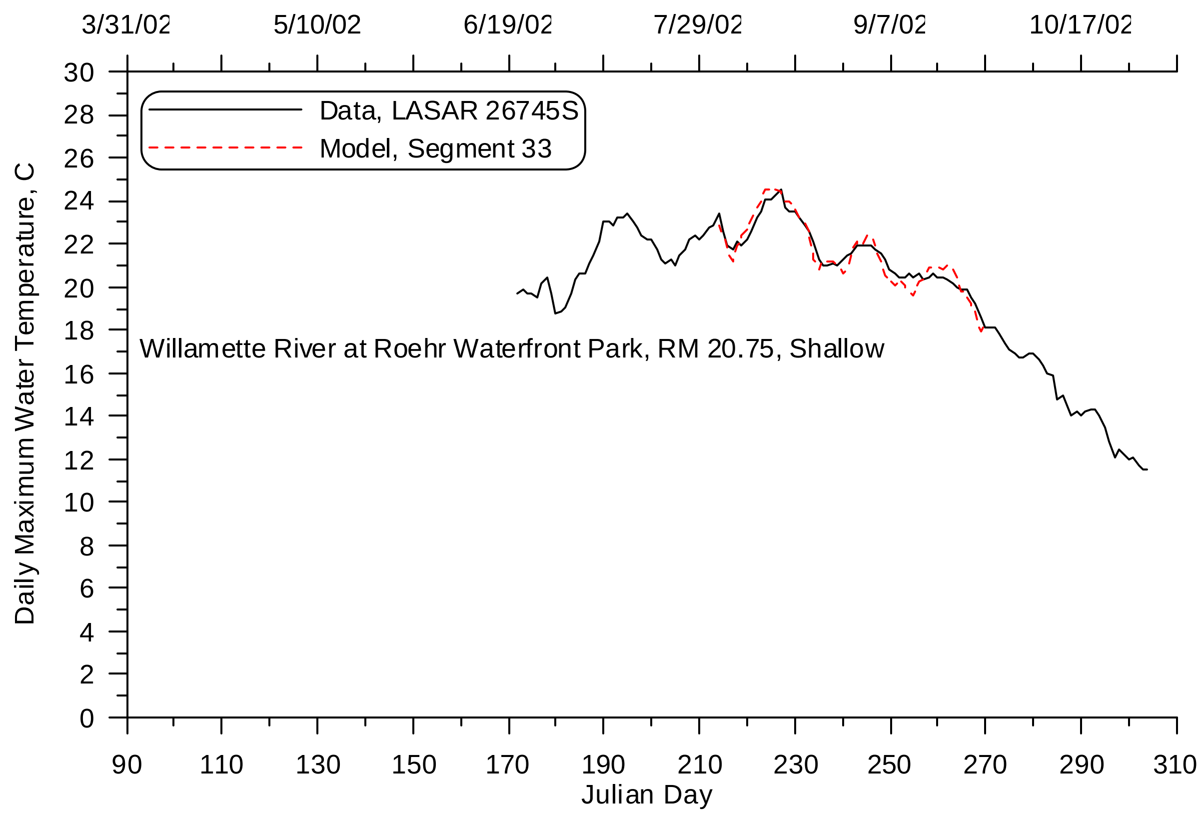

Figure 64: Willamette River at Roehr Waterfront Park (shallow) daily maximum temperature comparison, 2002

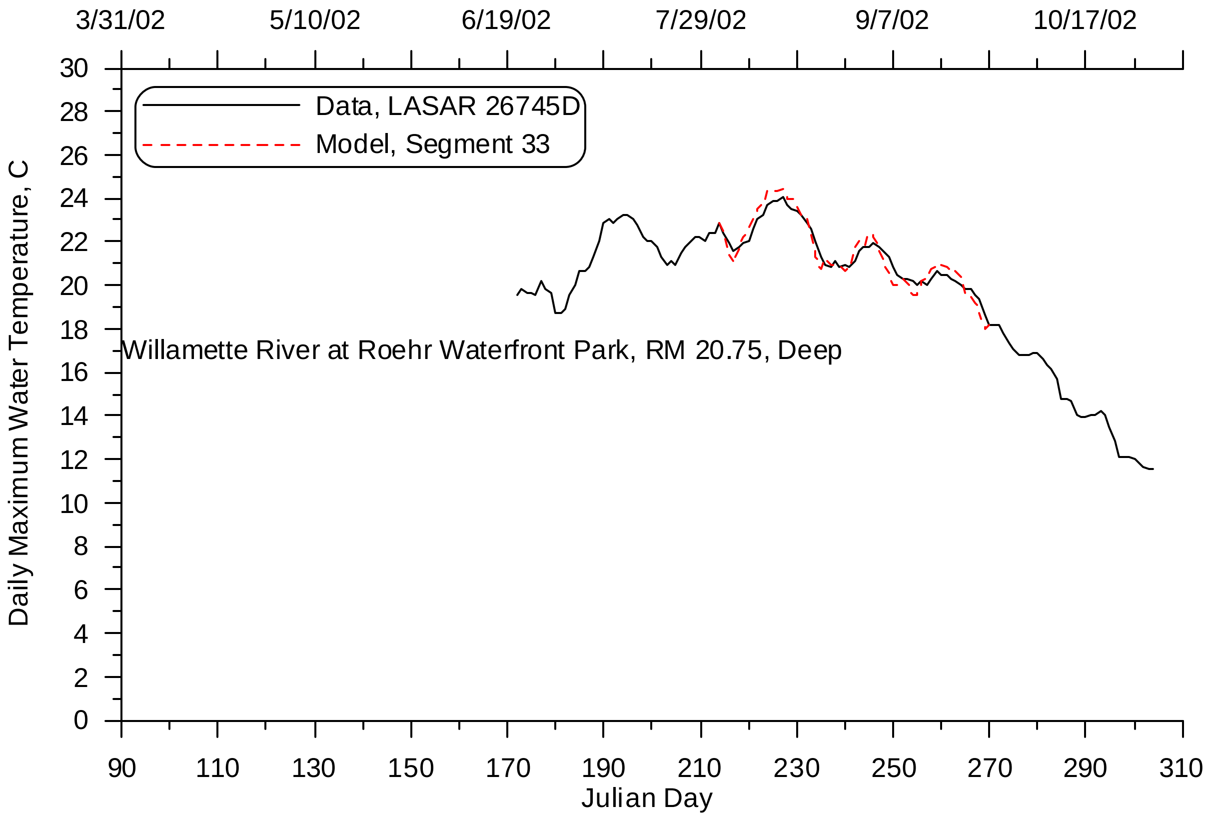

Figure 65: Willamette River at Roehr Waterfront Park (deep) daily maximum temperature comparison, 2002

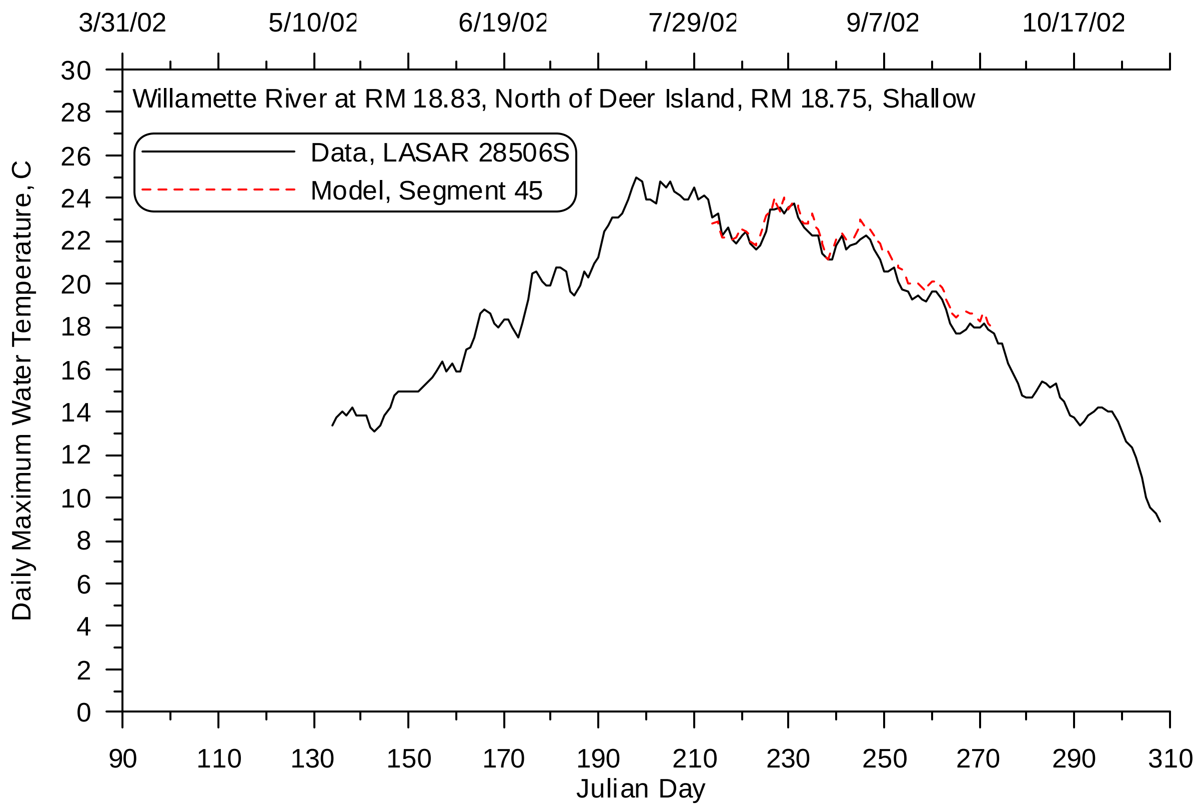

Figure 66: Willamette River north of Deer Island (shallow) model-data daily maximum temperature comparison, 2002

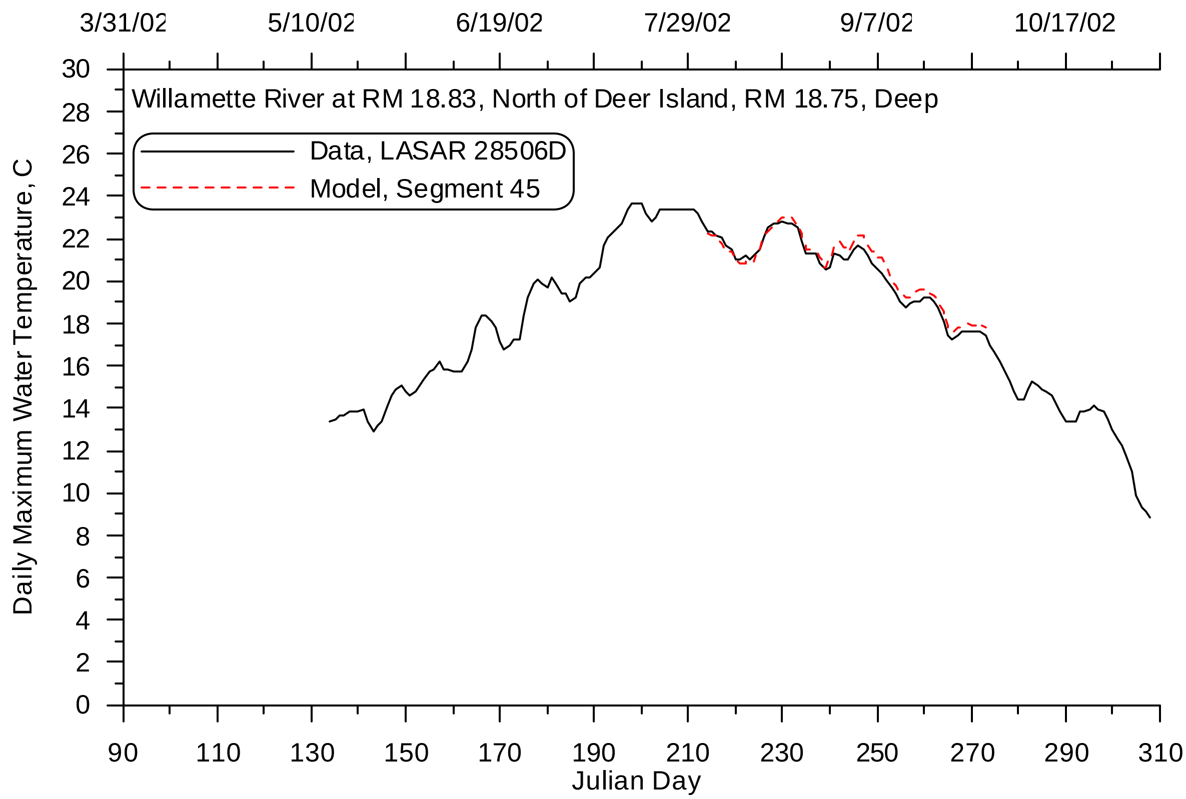

Figure 67: Willamette River north of Deer Island (deep) model-data daily maximum temperature comparison, 2002

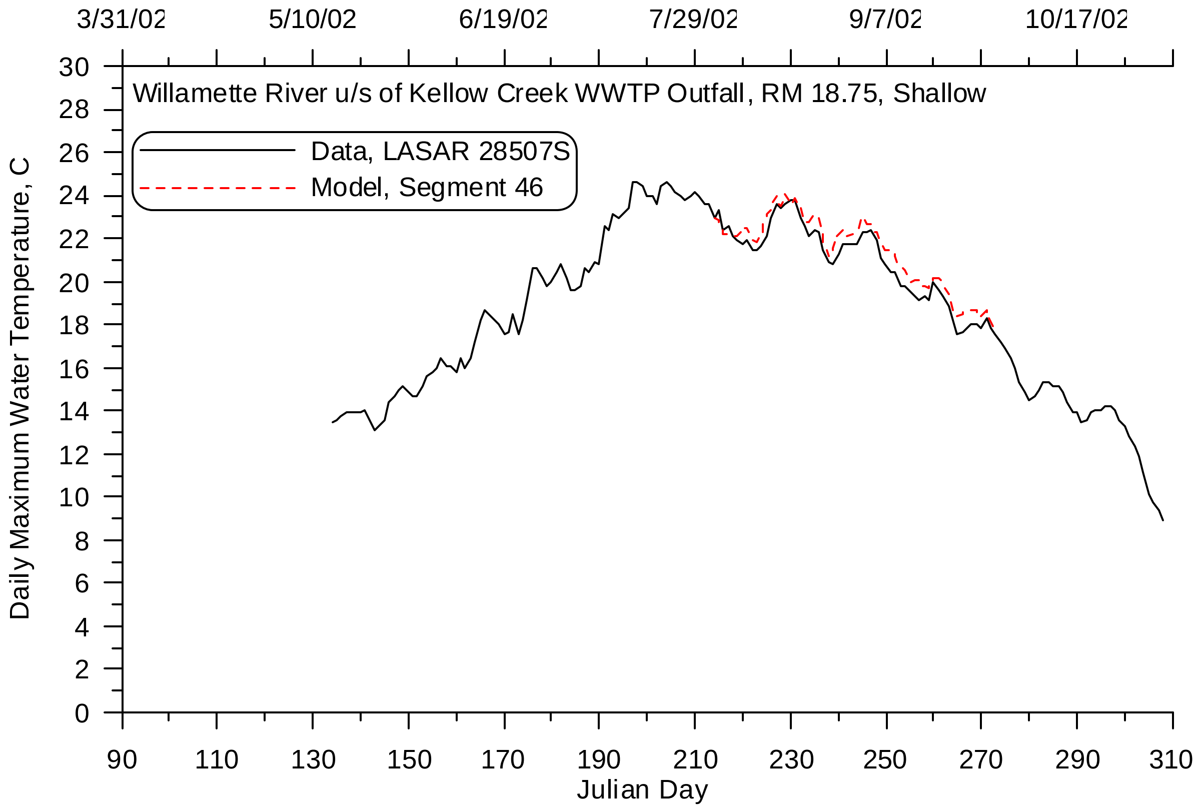

Figure 68: Willamette River upstream of Kellog Creek WWTP outfall (shallow) model-data daily maximum temperature comparison, 2002

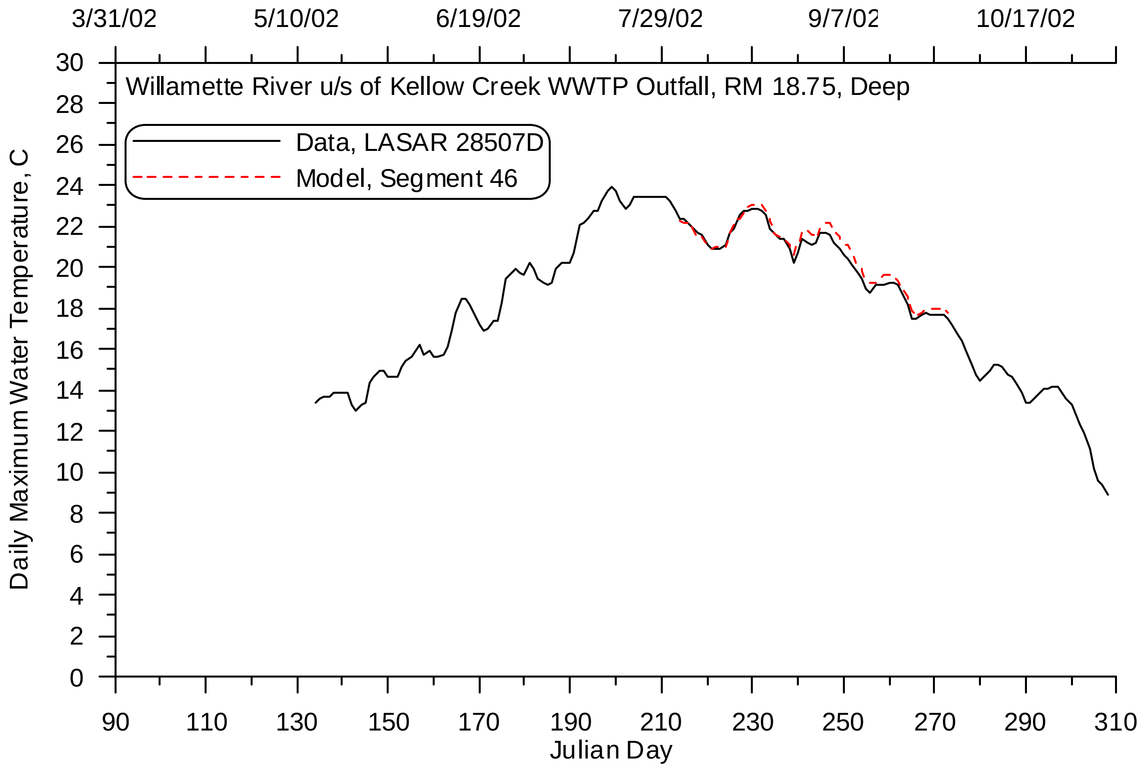

Figure 69: Willamette River upstream of Kellog Creek WWTP outfall (deep) model-data daily maximum temperature comparison, 2002

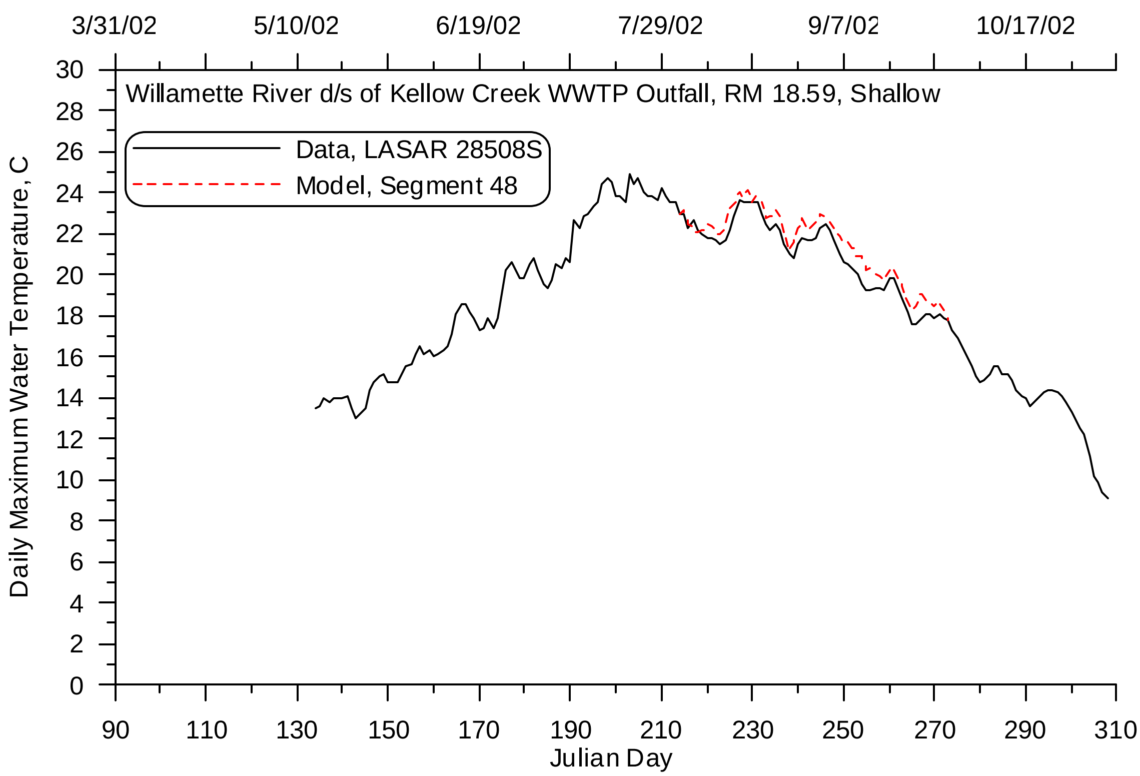

Figure 70: Willamette River downstream of Kellog Creek WWTP outfall (shallow) model-data daily maximum temperature comparison, 2002

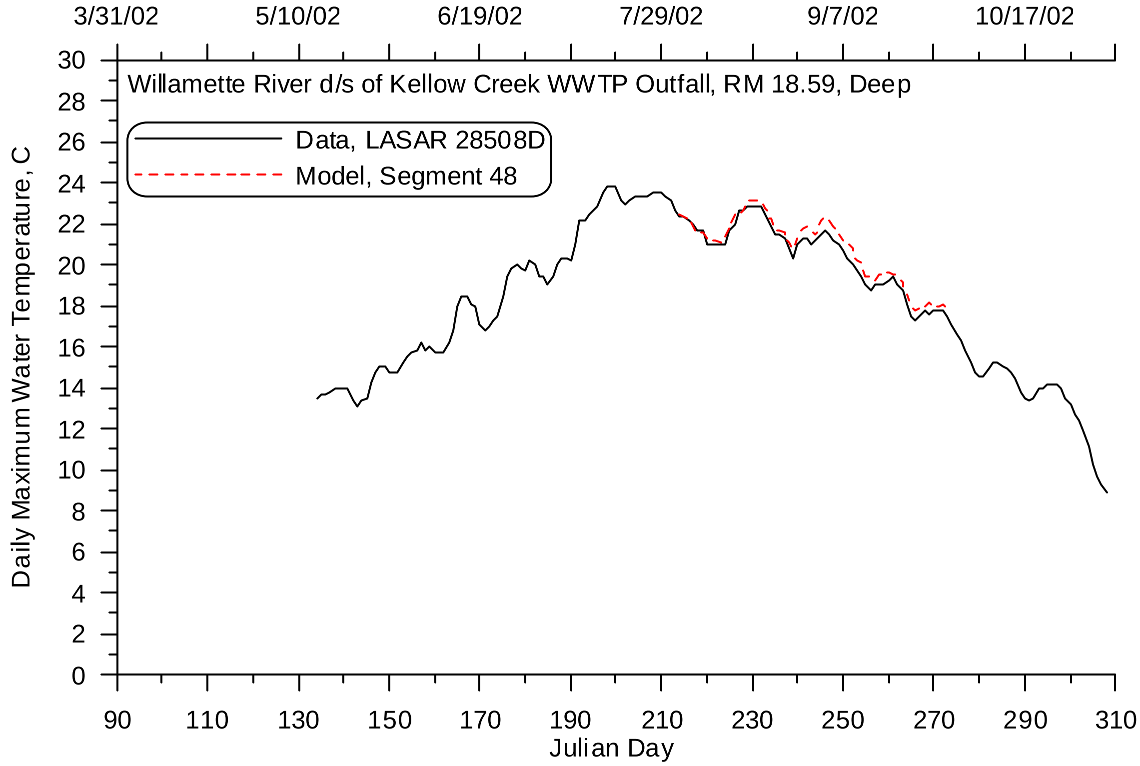

Figure 71: Willamette River downstream of Kellog Creek WWTP outfall (deep) model-data daily maximum temperature comparison, 2002

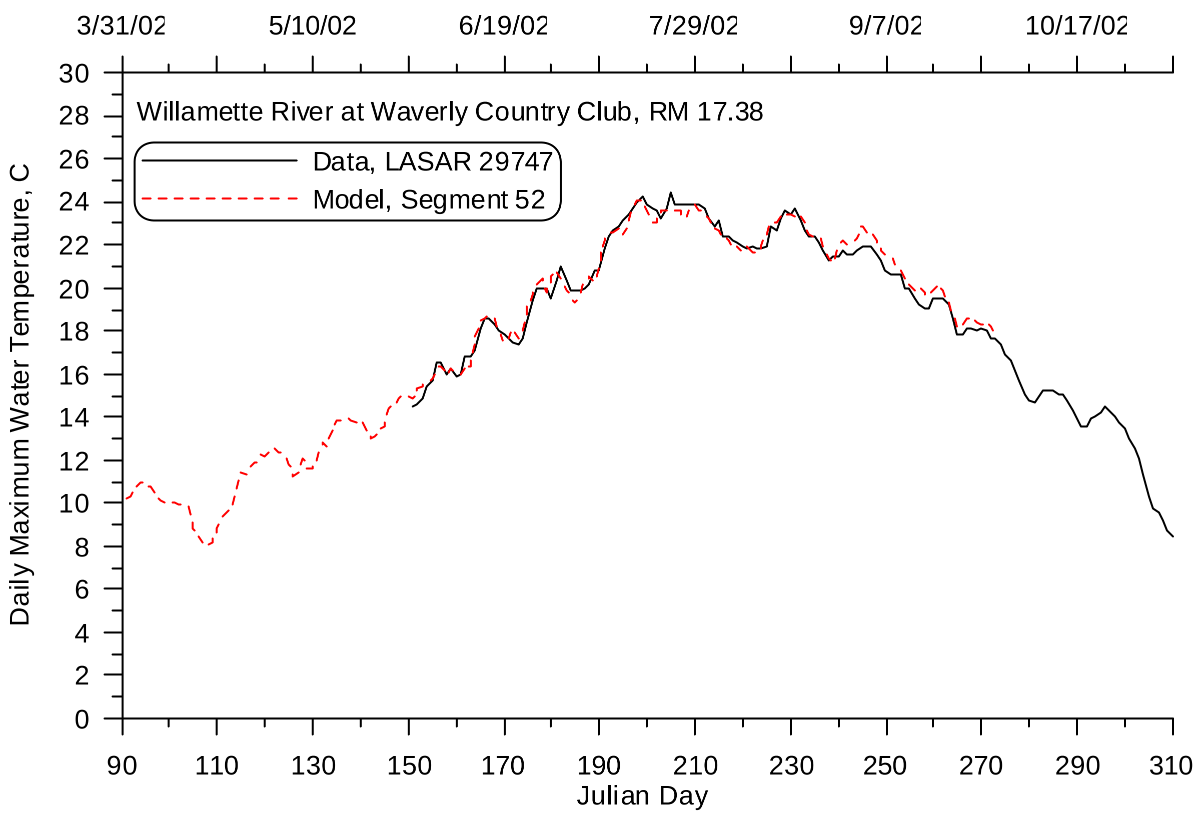

Figure 72: Willamette River at Waverly Country Club model-data daily maximum temperature comparison, 2002

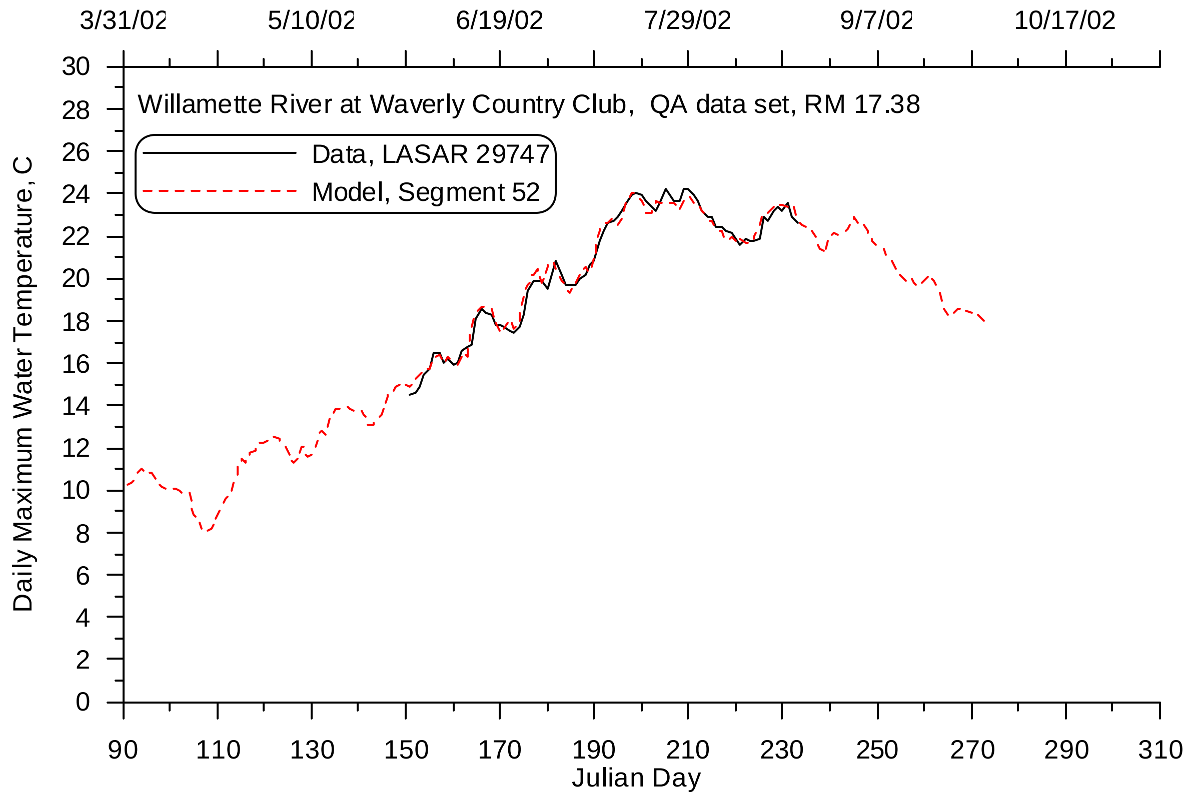

Figure 73: Willamette River at Waverly Country Club (QA data set) model-data daily maximum temperature comparison, 2002

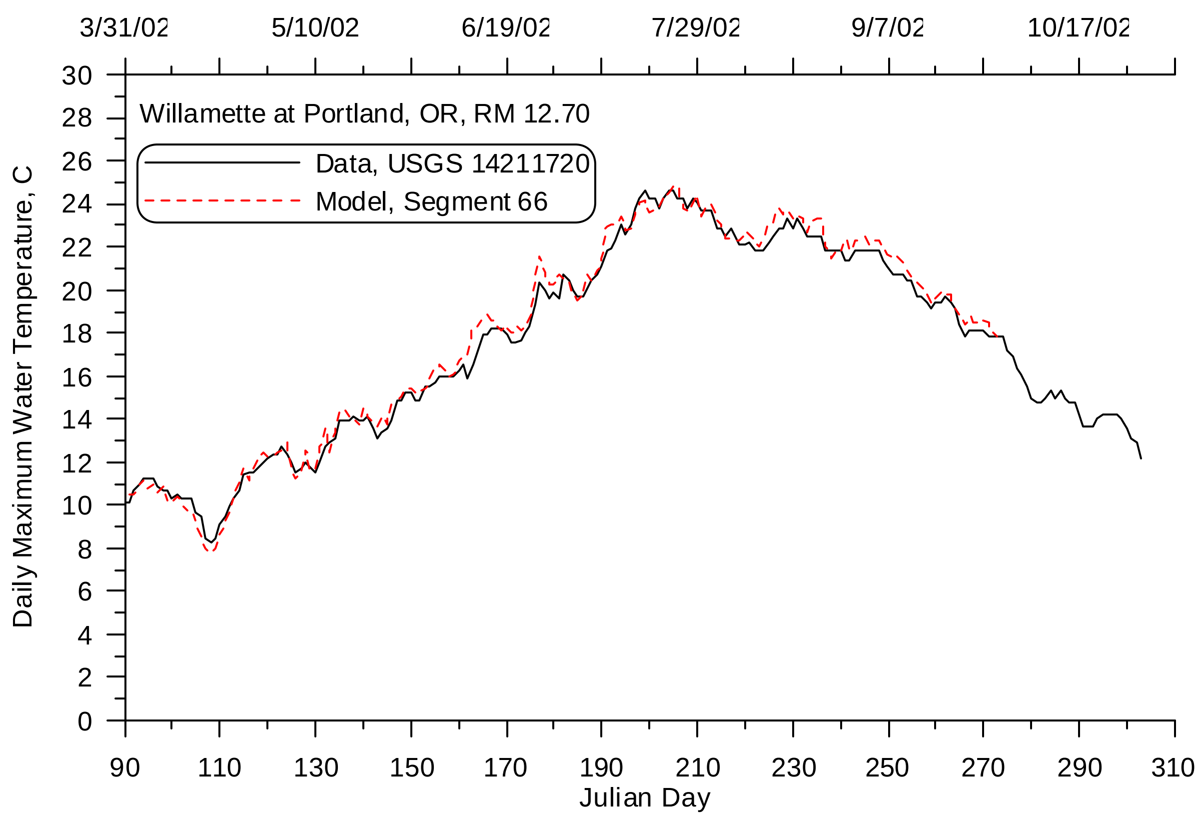

Figure 74: Willamette River at Portland model-data daily maximum temperature comparison, 2002

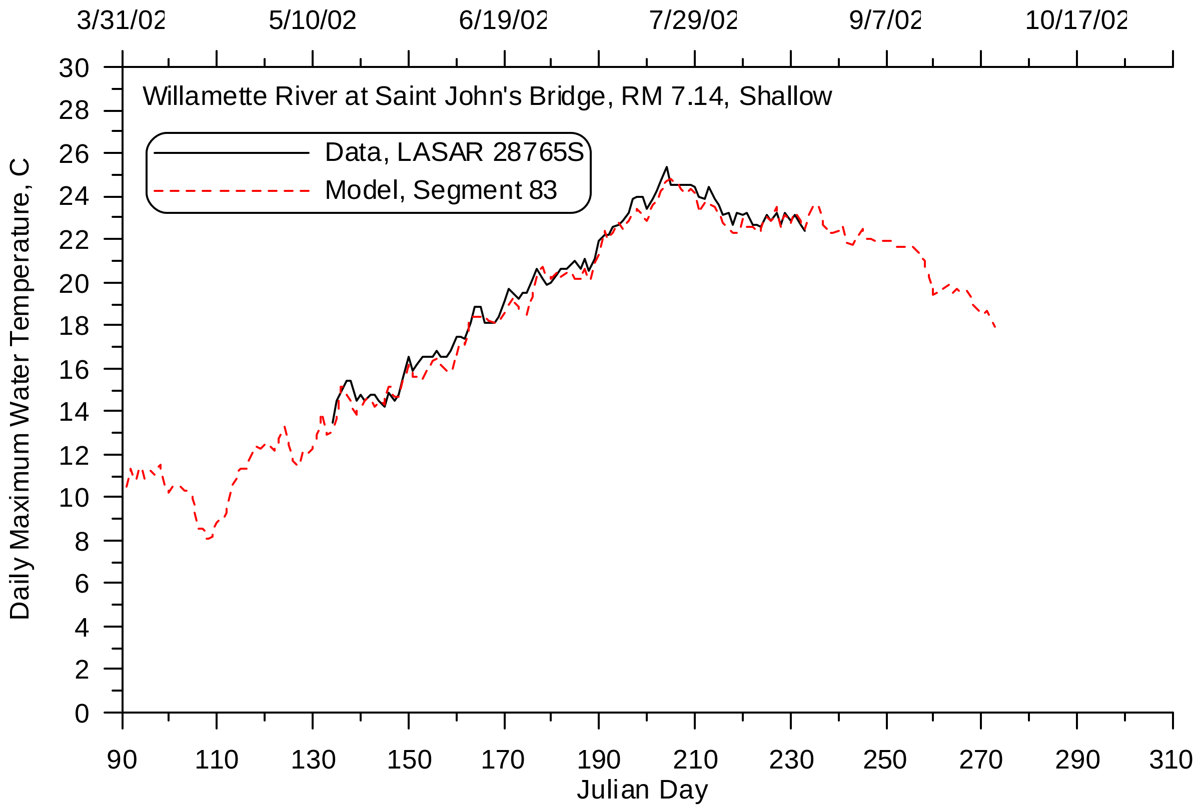

Figure 75: Willamette River at St. Johns Bridge (shallow) model-data daily maximum temperature comparison, 2002

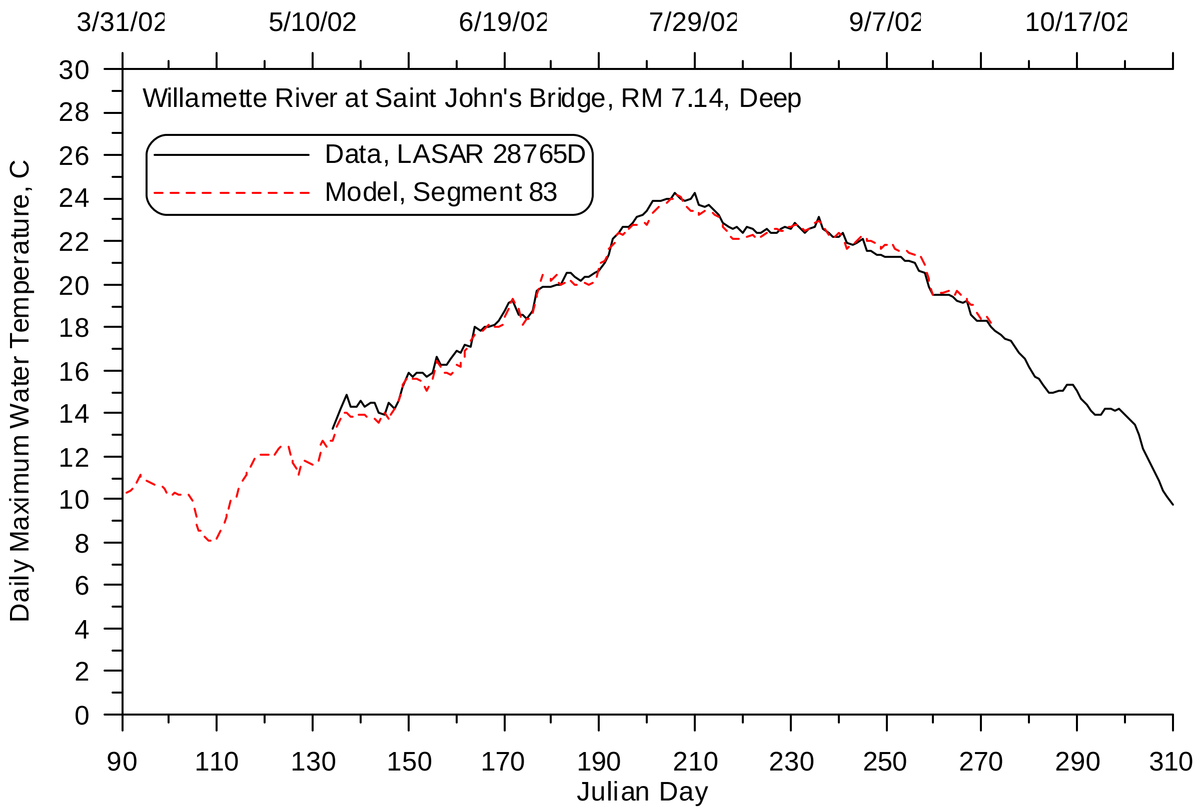

Figure 76: Willamette River at St. Johns Bridge (deep) model-data daily maximum temperature comparison, 2002

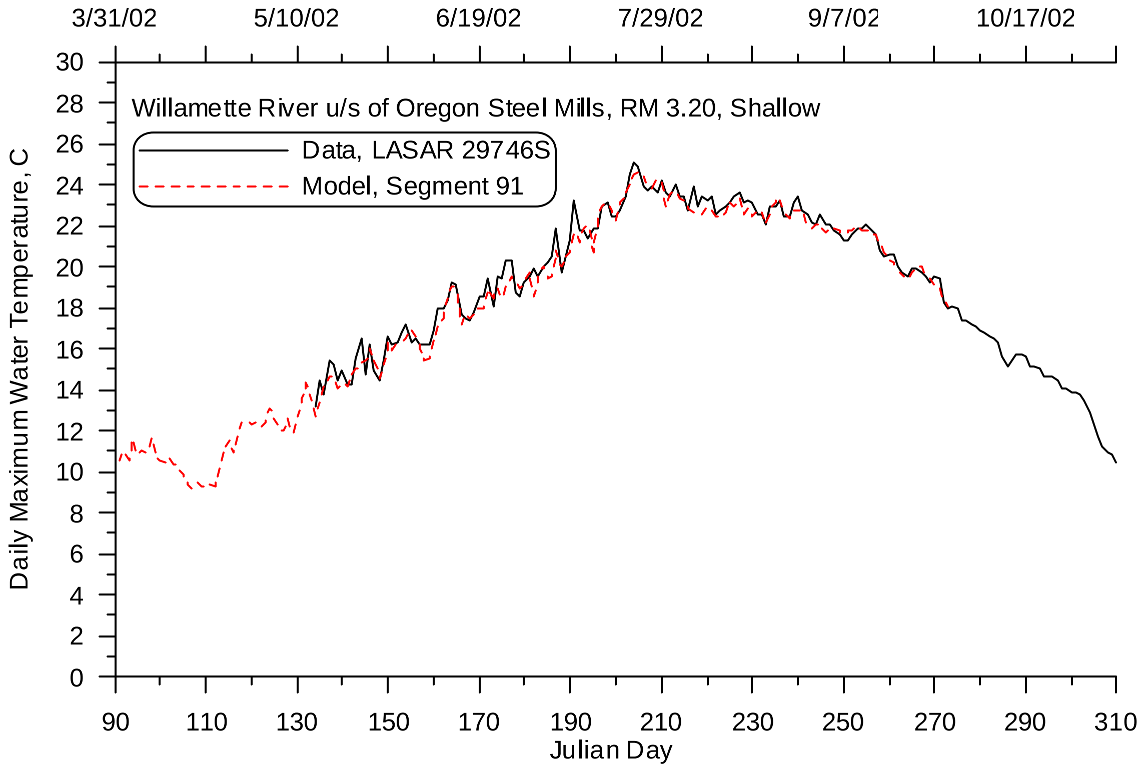

Figure 77: Willamette River upstream of Oregon Steel Mills (shallow) model-data daily maximum temperature comparison, 2002

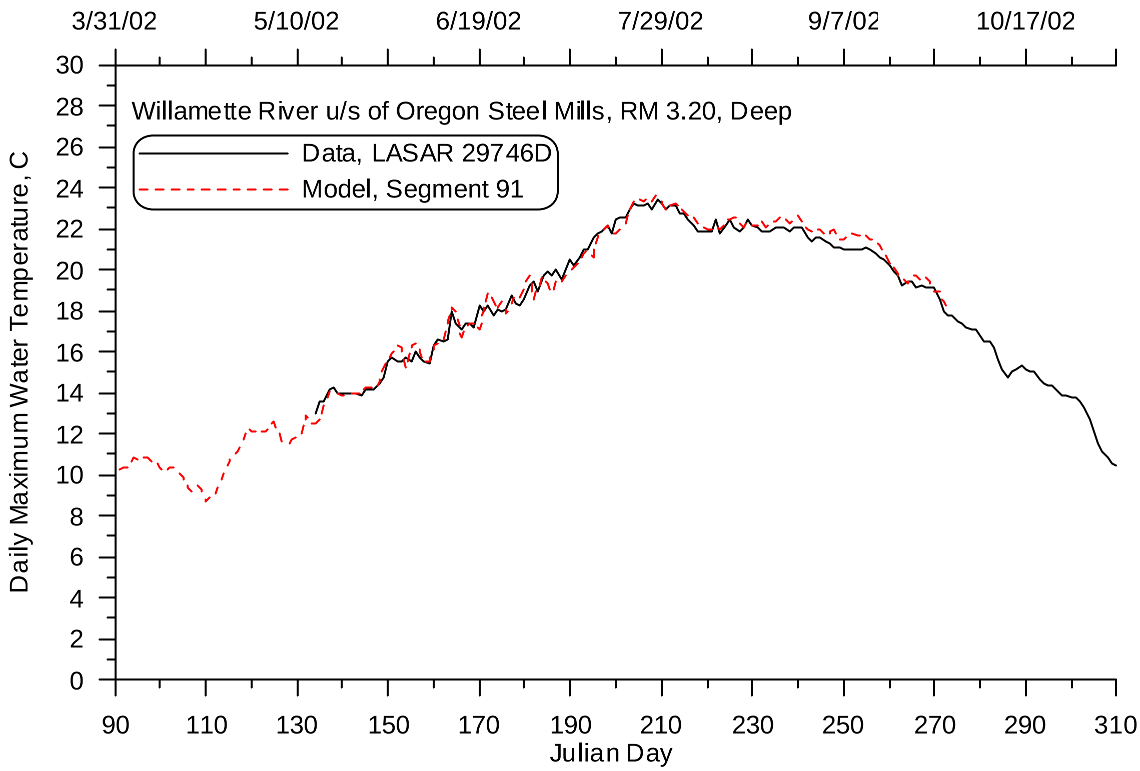

Figure 78: Willamette River upstream of Oregon Steel Mills (deep) model-data daily maximum temperature comparison, 2002

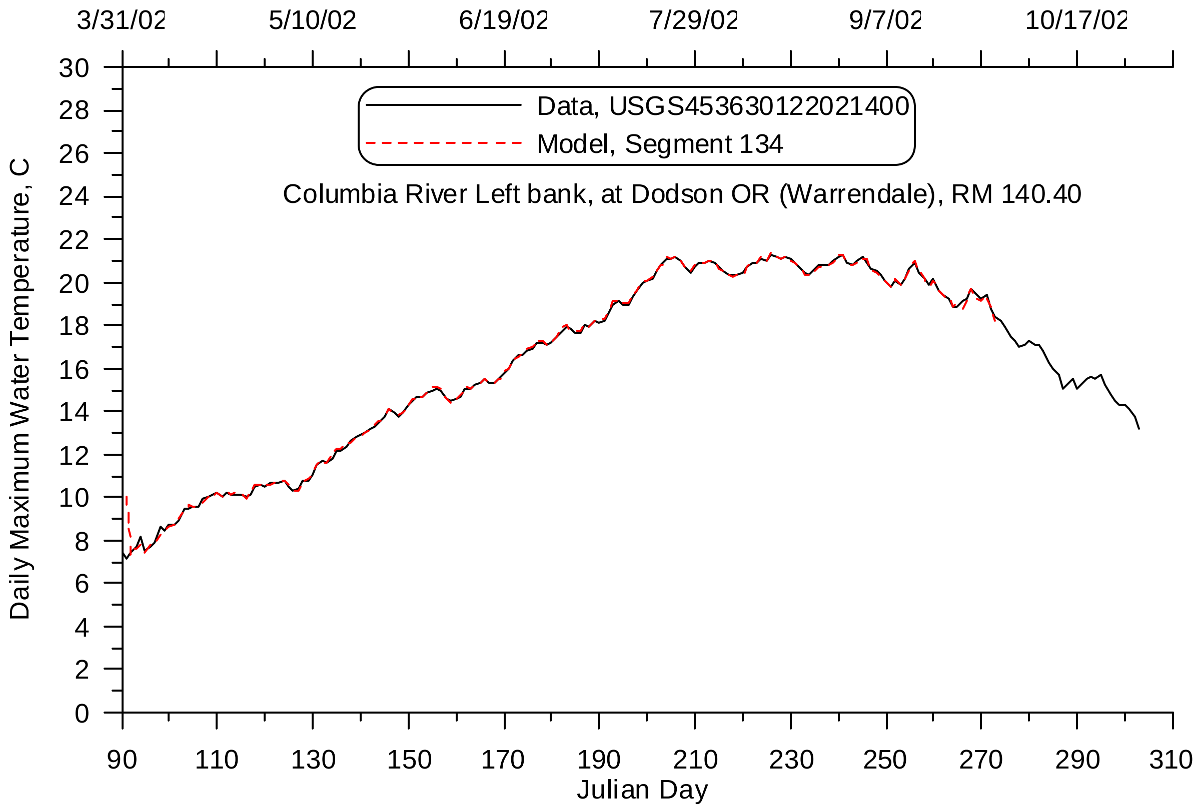

Figure 79: Columbia River left bank at Dodson, OR model-data daily maximum temperature comparison, 2002

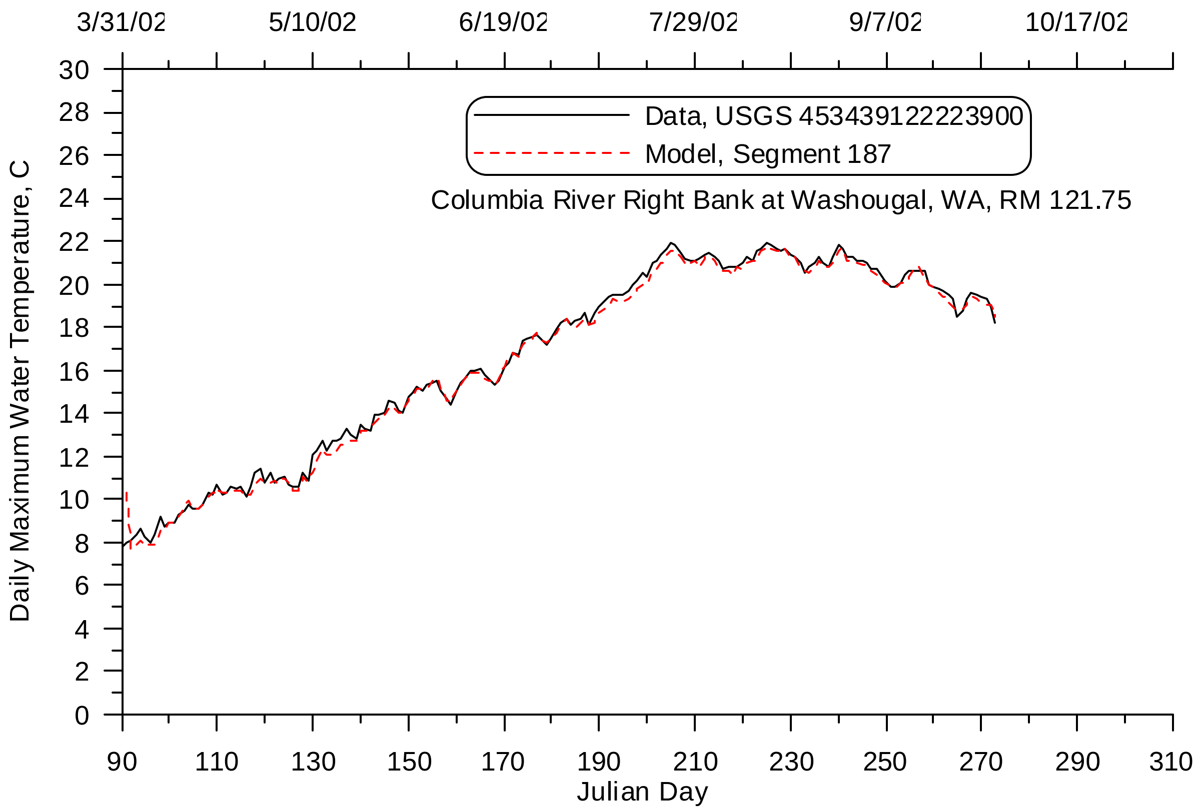

Figure 80: Columbia River at Washougal, WA model-data daily maximum temperature comparison, 2002

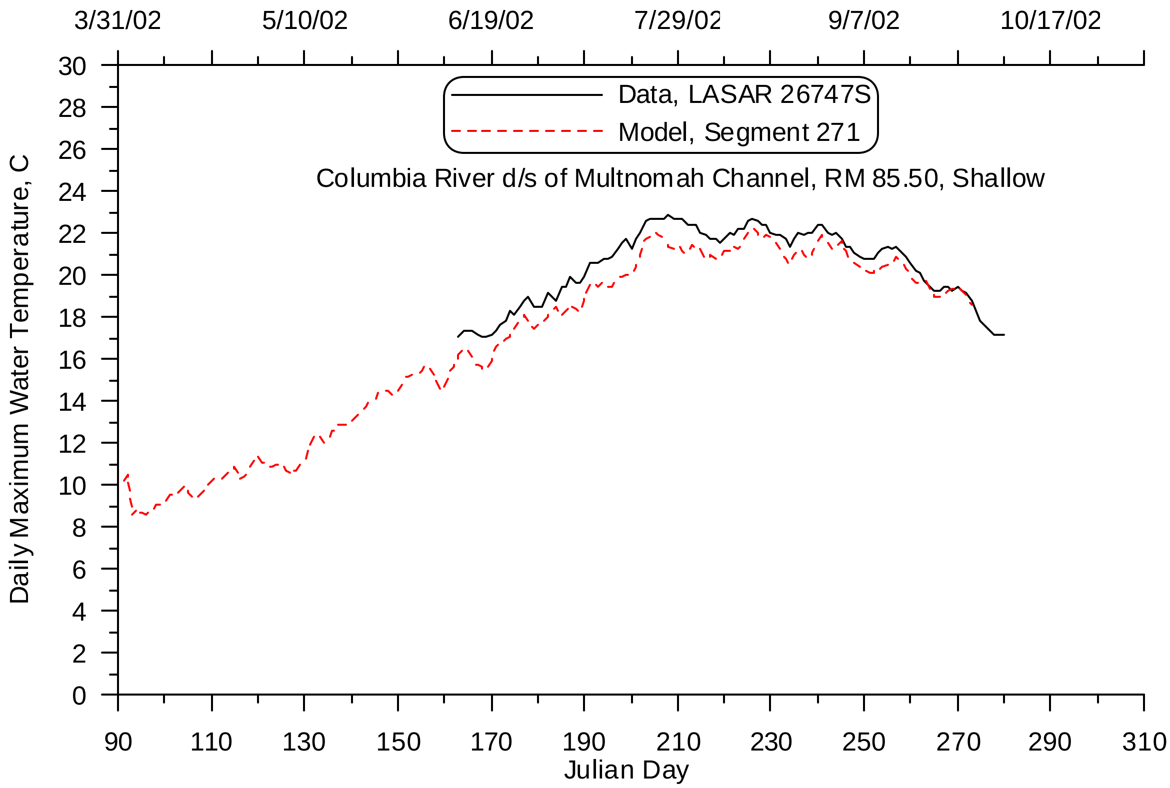

Figure 81: Columbia River downstream of Multnomah Channel (shallow) model-data daily maximum temperature comparison, 2002

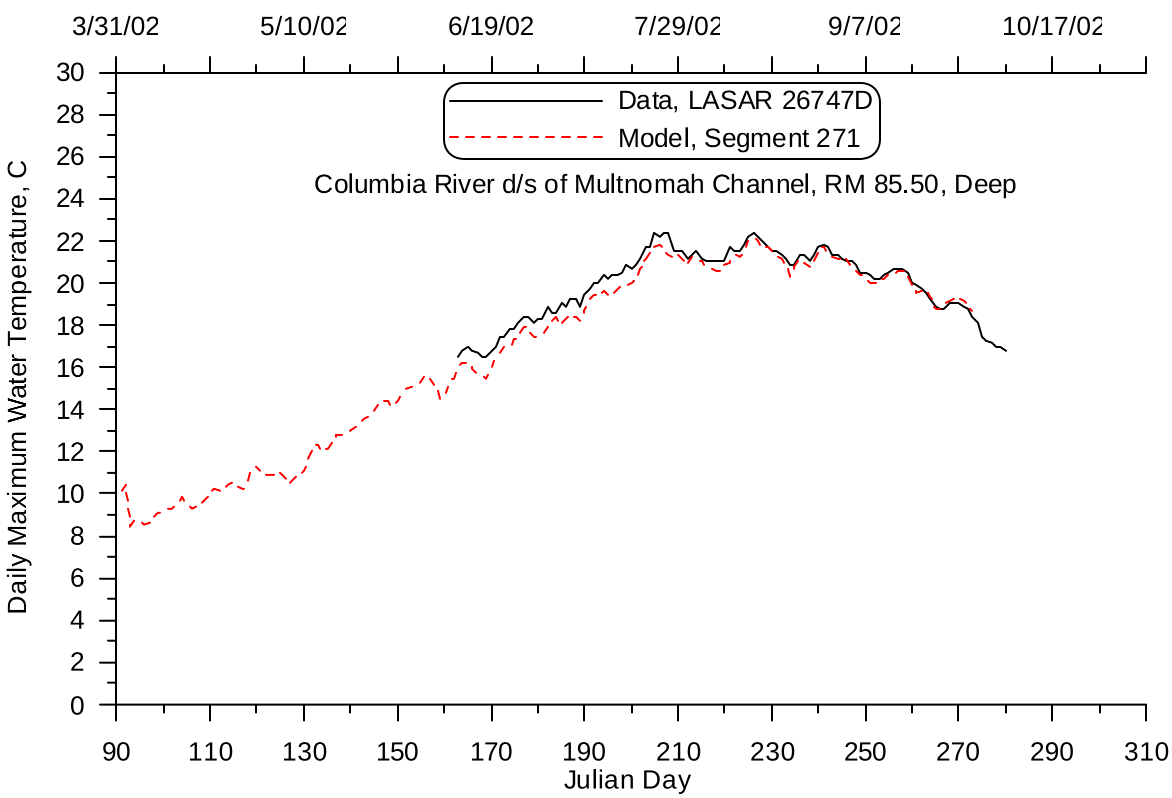

Figure 82: Columbia River downstream of Multnomah Channel (deep) model-data daily maximum temperature comparison, 2002

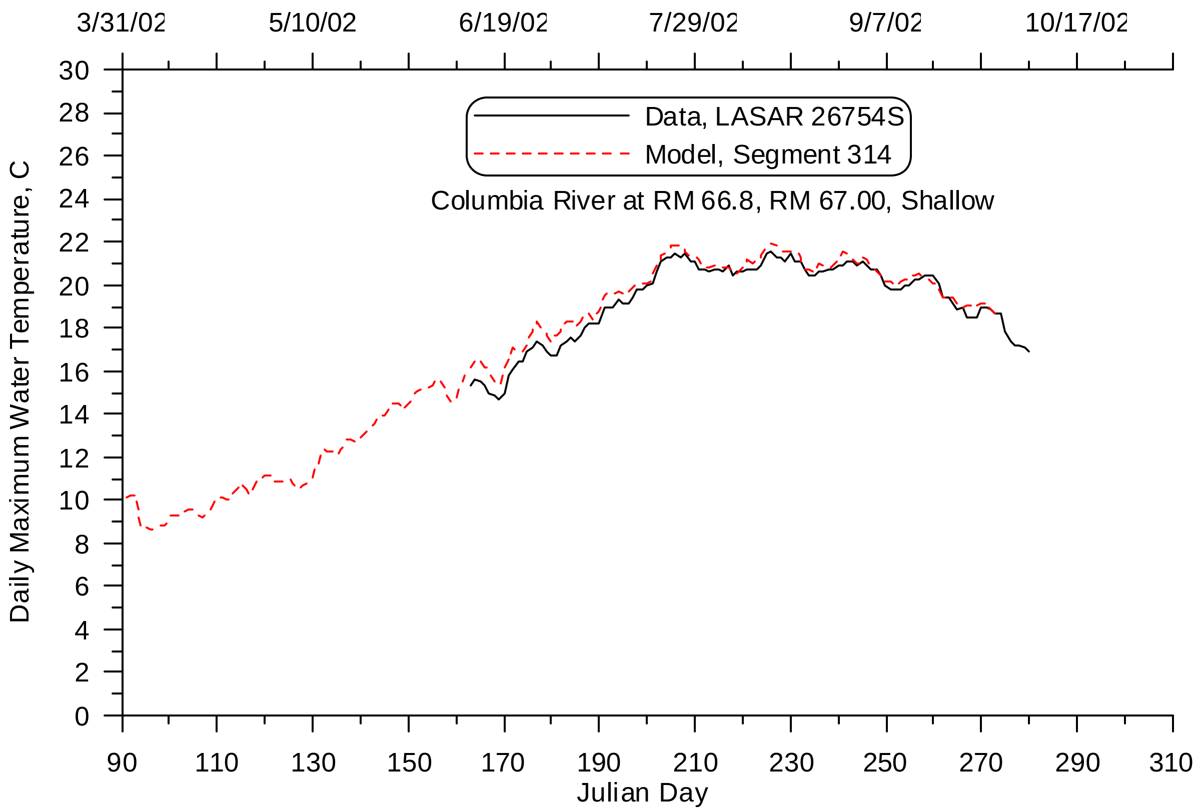

Figure 83: Columbia River at RM 66.8 (shallow) model-data daily maximum temperature comparison, 2002

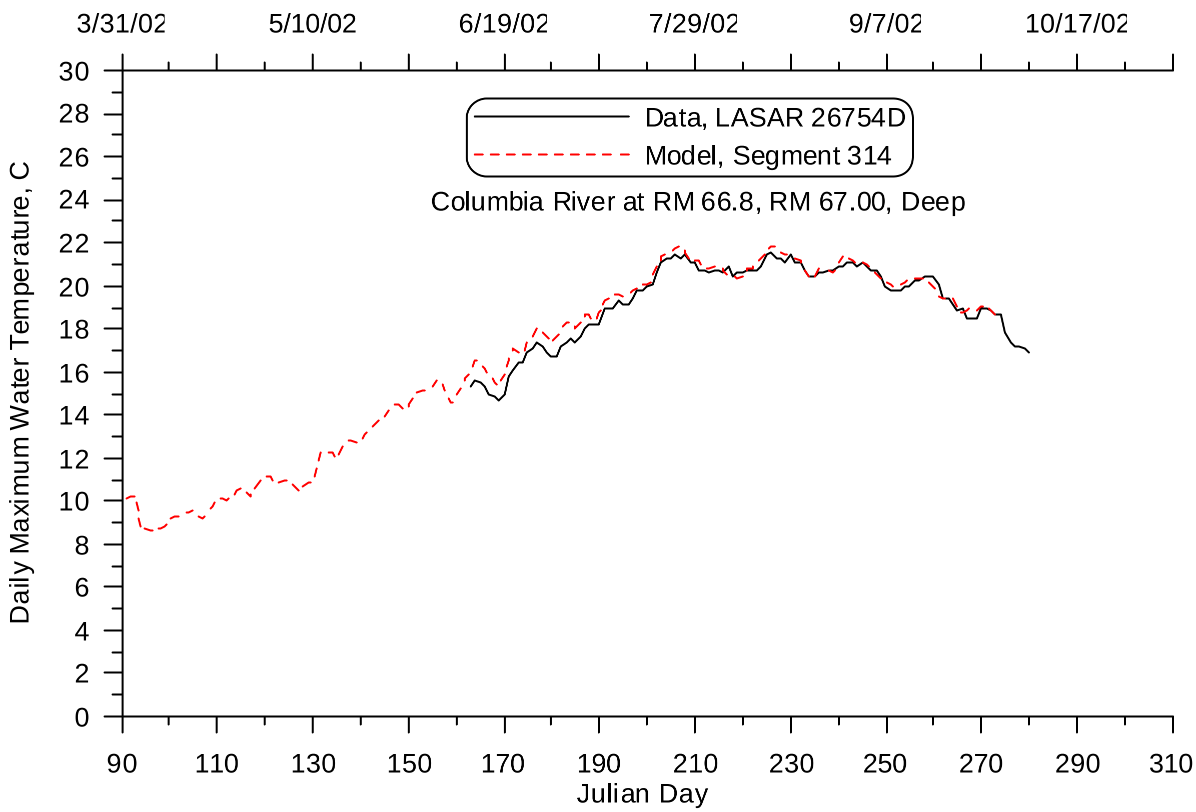

Figure 84: Columbia River at RM 66.8 (deep) model-data daily maximum temperature comparison, 2002

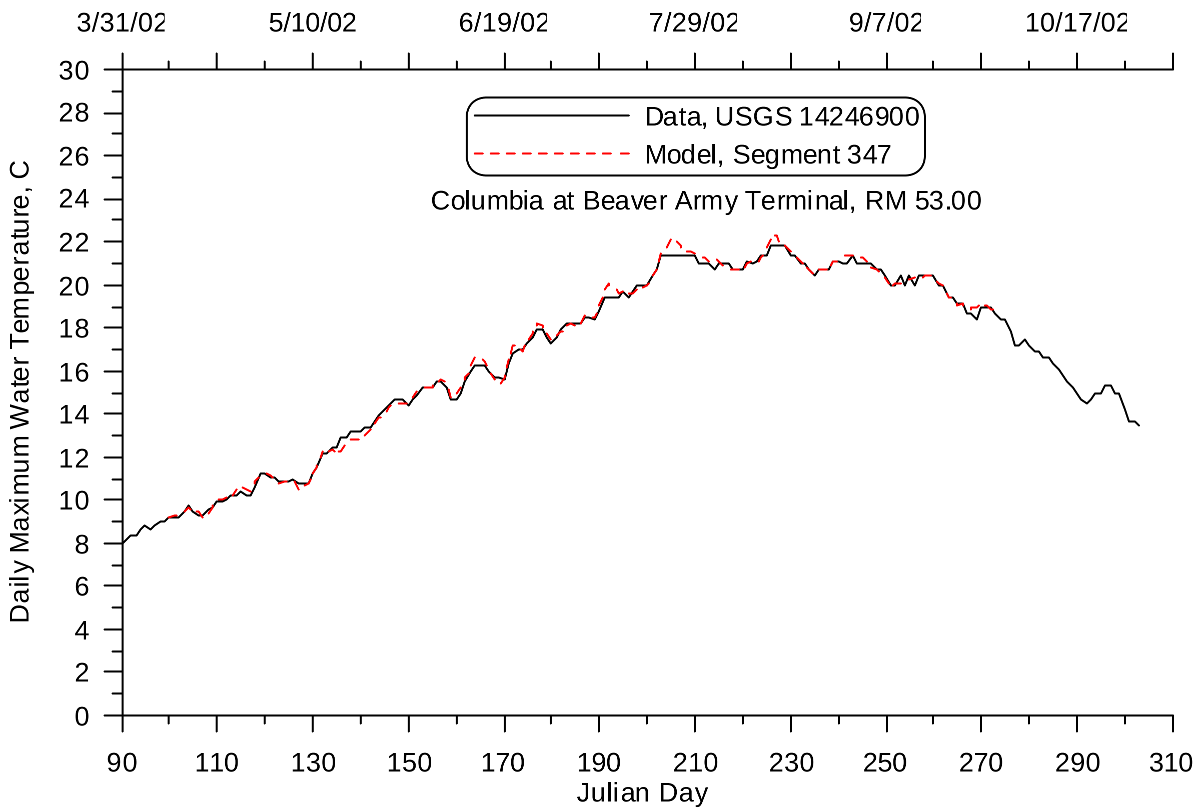

Figure 85: Columbia River at Beaver Army Terminal model-data daily maximum temperature comparison, 2002

Middle Willamette River

Introduction

The Middle Willamette River model was developed for the Willamette River from the Salem, Oregon, (RM 85.4) downstream to Willamette Falls in Oregon City (RM 26.8). Figure 86 shows the model region along with several cities and drainage areas within the model region. The model drains approximately 25,600 km^2 of the Willamette River Basin.

The model calibration period was from July 26 to September 30, 2001, and from April 1 to October 1, 2002. The data needed to support the model consisted of three components: the river channel bathymetry, the meteorological conditions and the boundary condition inflows and temperatures.

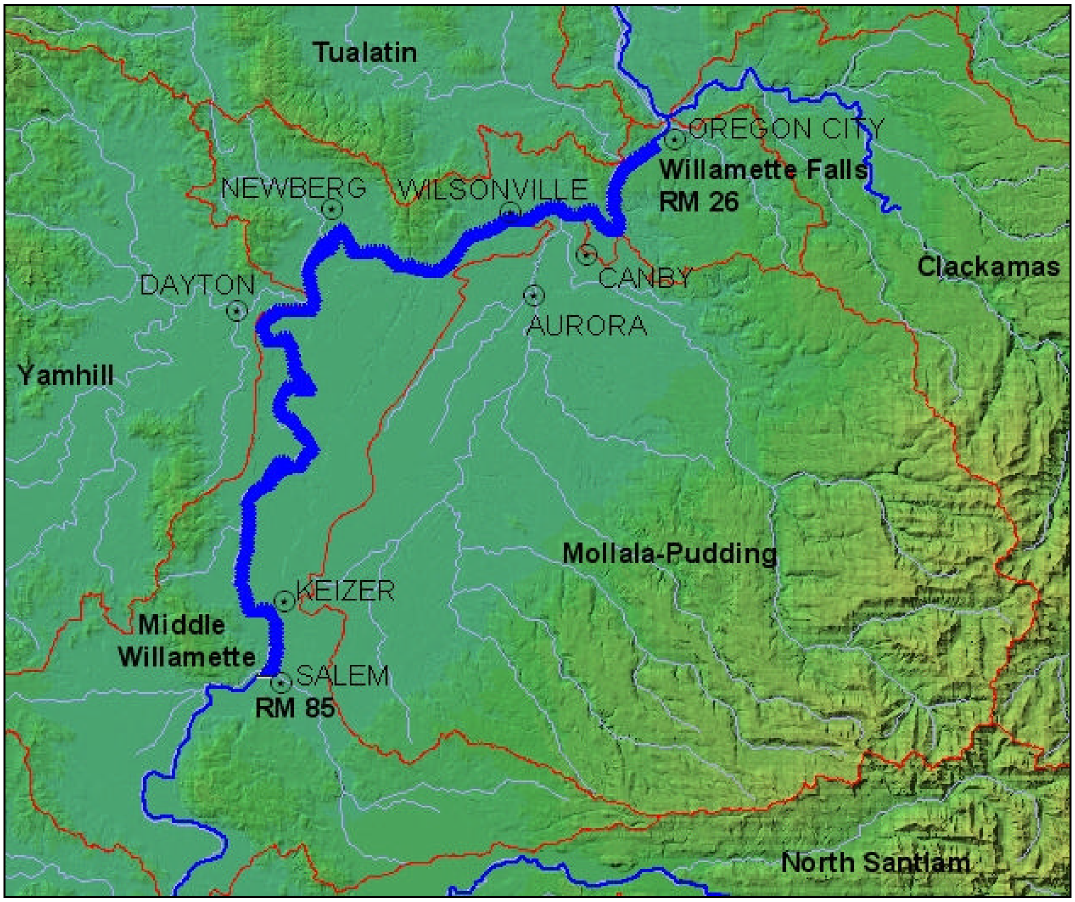

Figure 86: Middle Willamette River model region

Hydrodynamics

Hydrodynamics were calibrated using water level and flow data. The only calibration parameters used were Manning's friction factor, adjustments to the channel slope and the channel widths since there was limited bathymetric data for the river.

Flow and Water Surface Elevation

The Middle Willamette River model has three gage stations with continuous water surface elevation and flow data for calibrating the model. Figure 87 shows a map of the basin with the gage site locations and Table 12 shows a list of the gage sites, their RM, and corresponding model segment.

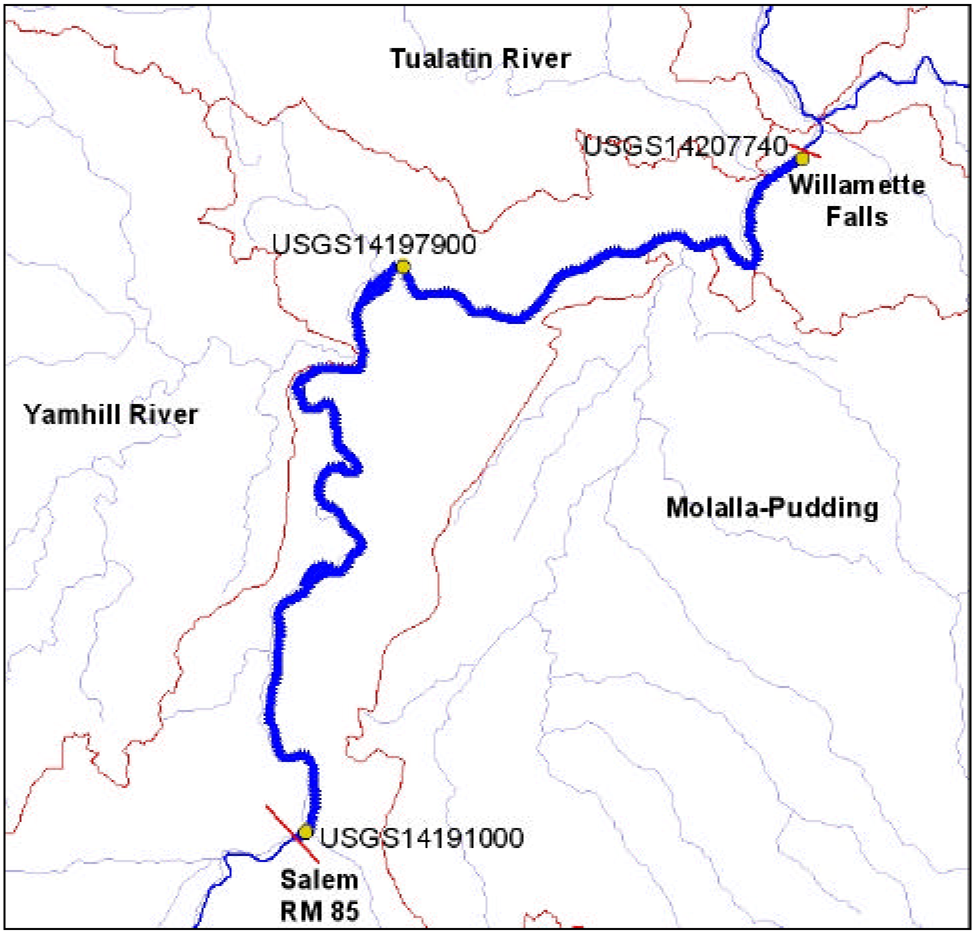

Figure 87: Middle Willamette River hydrodynamic calibration site locations

Table 12: Middle Willamette River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14191000	Willamette River at Salem, OR	84.69	5	Q & WL
USGS 14197900	Willamette River at Newberg, OR	50.11	246	WL, 2002 only
USGS 14207740	Willamette River above Willamette Falls	26.81	396	WL

Year 2001

Hydrodynamic calibration of the Middle Willamette River model required setting the weir parameters for the Willamette Falls and adjusting the Manning's friction factor on a segment by segment basis. Manning's friction factors were also adjusted during the temperature calibration. Flashboards are used to increase available head for hydropower at the Willamette Falls, and typically these boards are blown out after winter rains increase flow. The weir coefficient representing the Willamette Falls had to be calibrated to a value where model predicted water levels matched data. Manning's *n* was calibrated to values from 0.02 to 0.04. Water level and flow statistics for the 2001 Middle Willamette River model are shown in Table 13. Figure 88 through Figure 90 show model-data comparison of flow and water levels. The figures show the model is simulating the amount of water well which then passes in the Lower Willamette River model. There are some discrepancies in the water surface elevation just above the Willamette Falls but this can be attributed to some inaccuracies it gage station data due its location. Regardless there is still reasonable agreement between the model and data above the Willamette Falls.

Table 13: Middle Willamette River hydrodynamic calibration statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14191000	84.69	5	3096	-0.05	0.13	0.20
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14191000	84.69	5	3096	-0.06	0.06	0.06
USGS 14207740	26.81	396	3096	-0.04	0.07	0.10

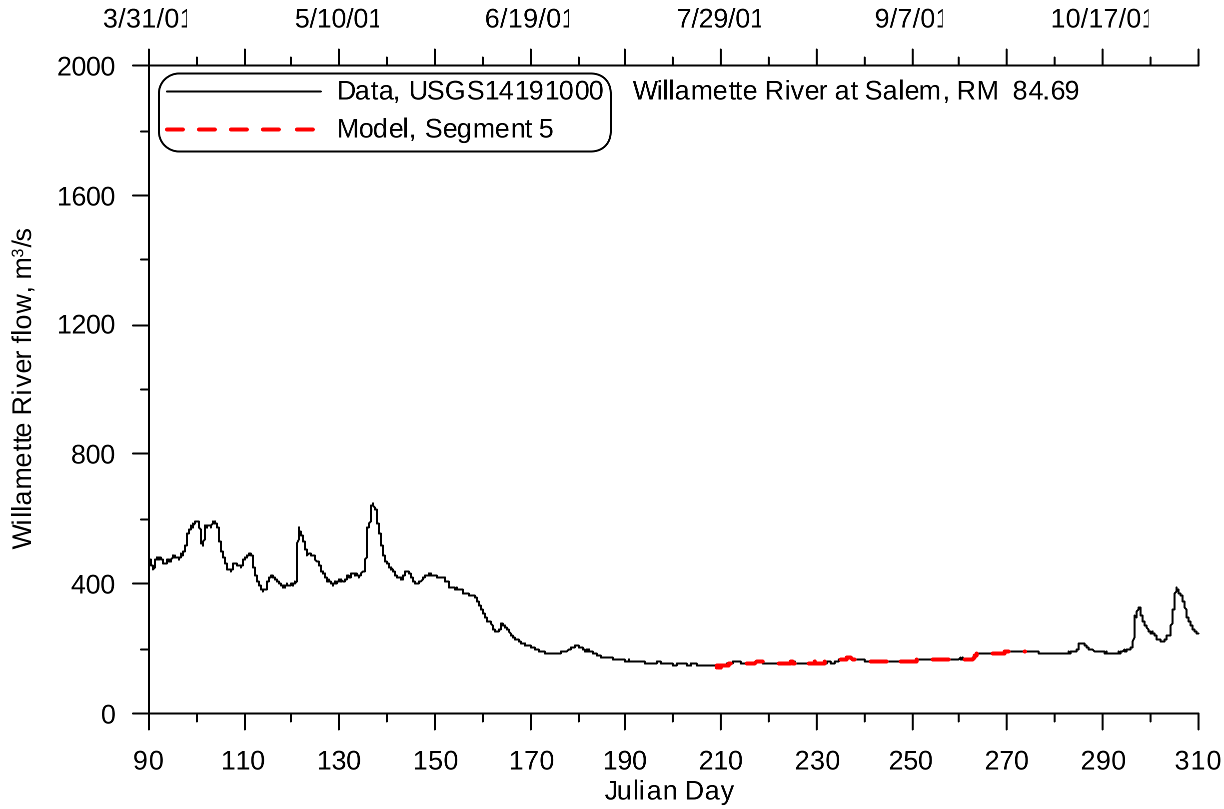

Figure 88: Willamette River at Salem model-data flow comparison, 2001

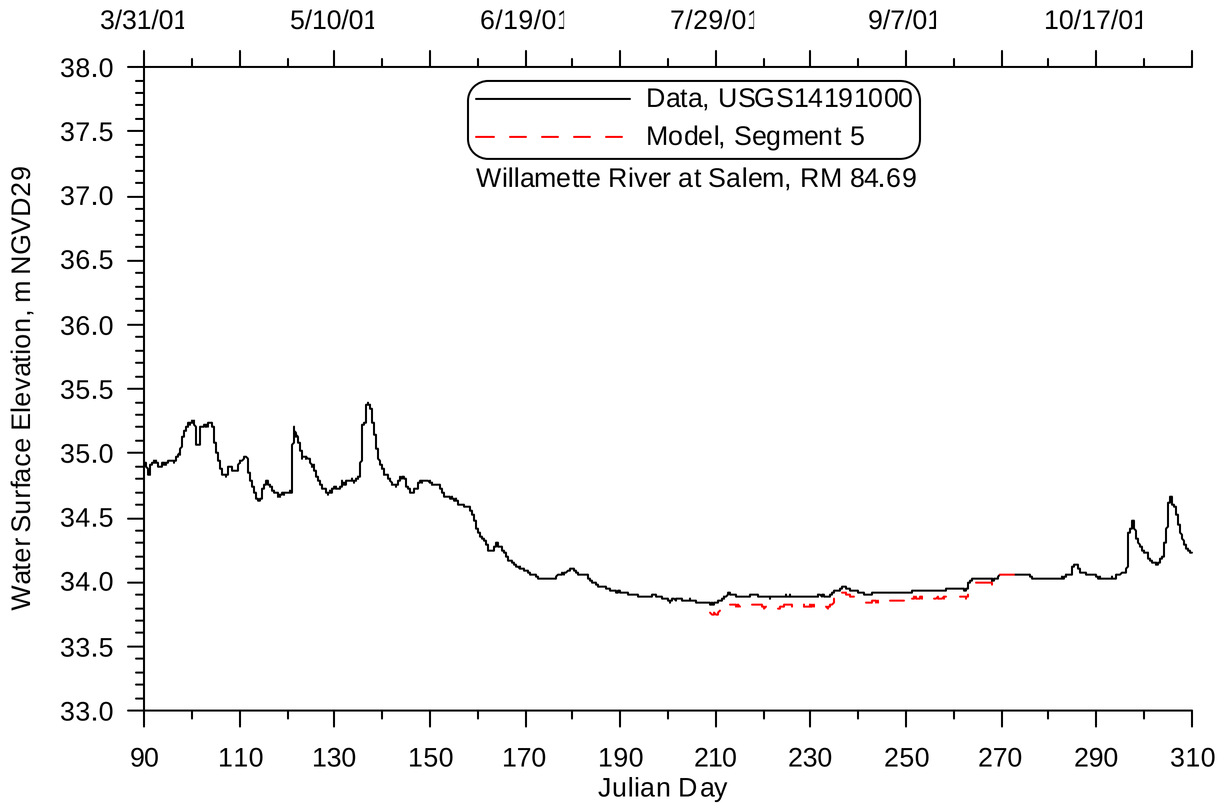

Figure 89: Willamette River at Salem model-data water level comparison, 2001

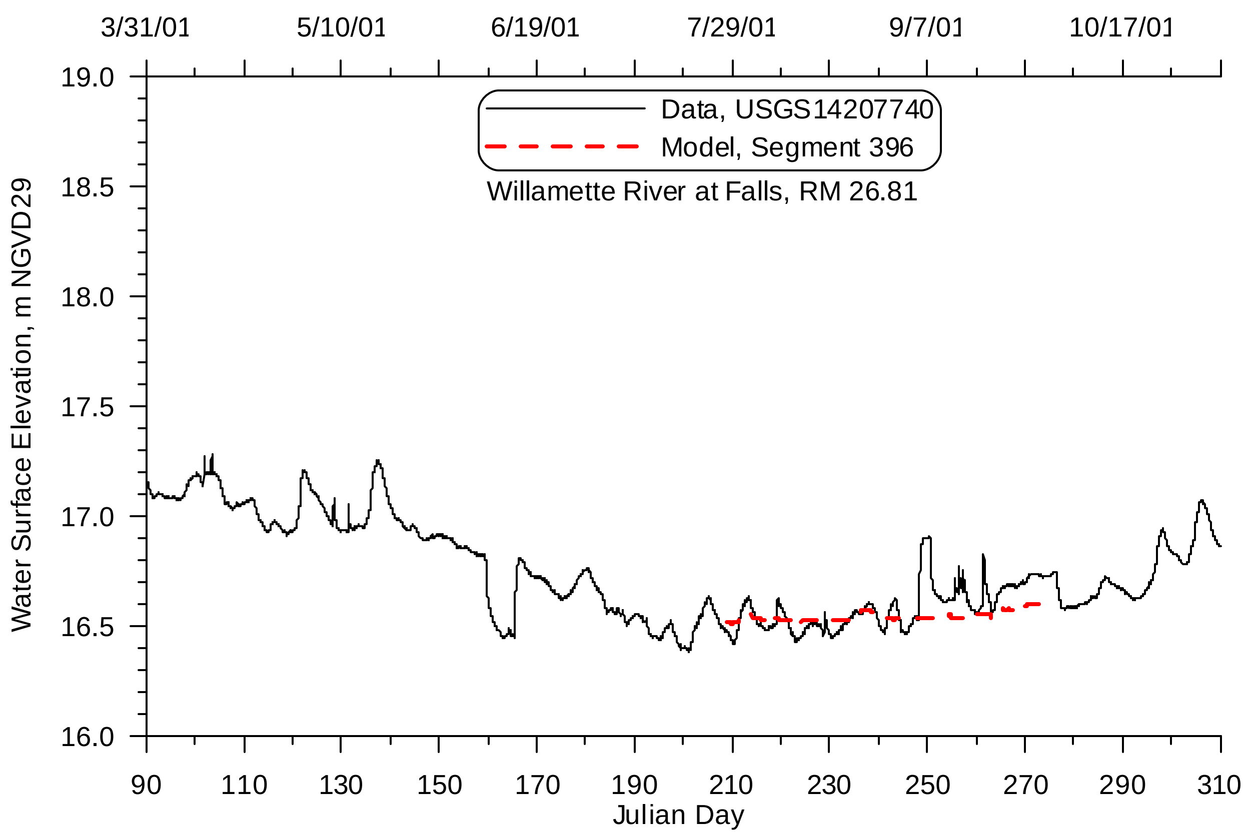

Figure 90: Willamette River at the Willamette Falls model-data water level comparison, 2001

Year 2002

Since the number of flashboards installed at the Willamette Falls can vary, the weir settings were different than those of 2001. Table 14 lists hydrodynamic calibration statistics for the Middle Willamette River 2002 model. The plots shown in Figure 91 through Figure 94 compare water level and flow predictions with data. The time series plot show there is good model-data agreement both during higher flows in the spring and lower flows in the summer, with less agreement during the highest flow period in late April. This slight disagreement in the flows in late April explain why the flows do not match as well in the Lower Willamette River model during the same time period. Overall there is good agreement with flow and water level comparisons between Salem and the Willamette Falls.

Table 14: Middle Willamette River hydrodynamic calibration statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14191000	84.69	5	8736	0.14	0.44	0.87
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14191000	84.69	5	8736	0.06	0.06	0.07
USGS 14197900	50.11	246	8736	0.09	0.11	0.22
USGS 14207740	26.81	396	17470	0.02	0.03	0.05

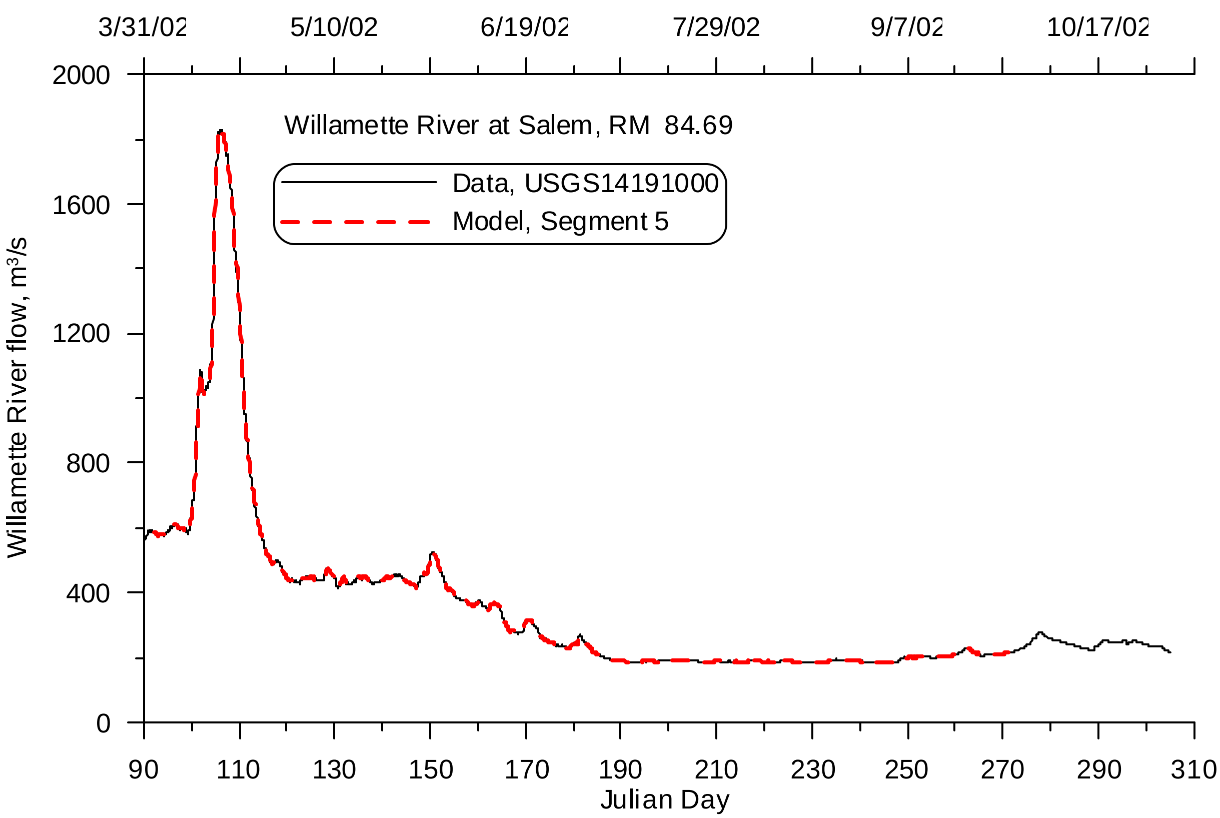

Figure 91: Willamette River at Salem model-data flow comparison, 2001

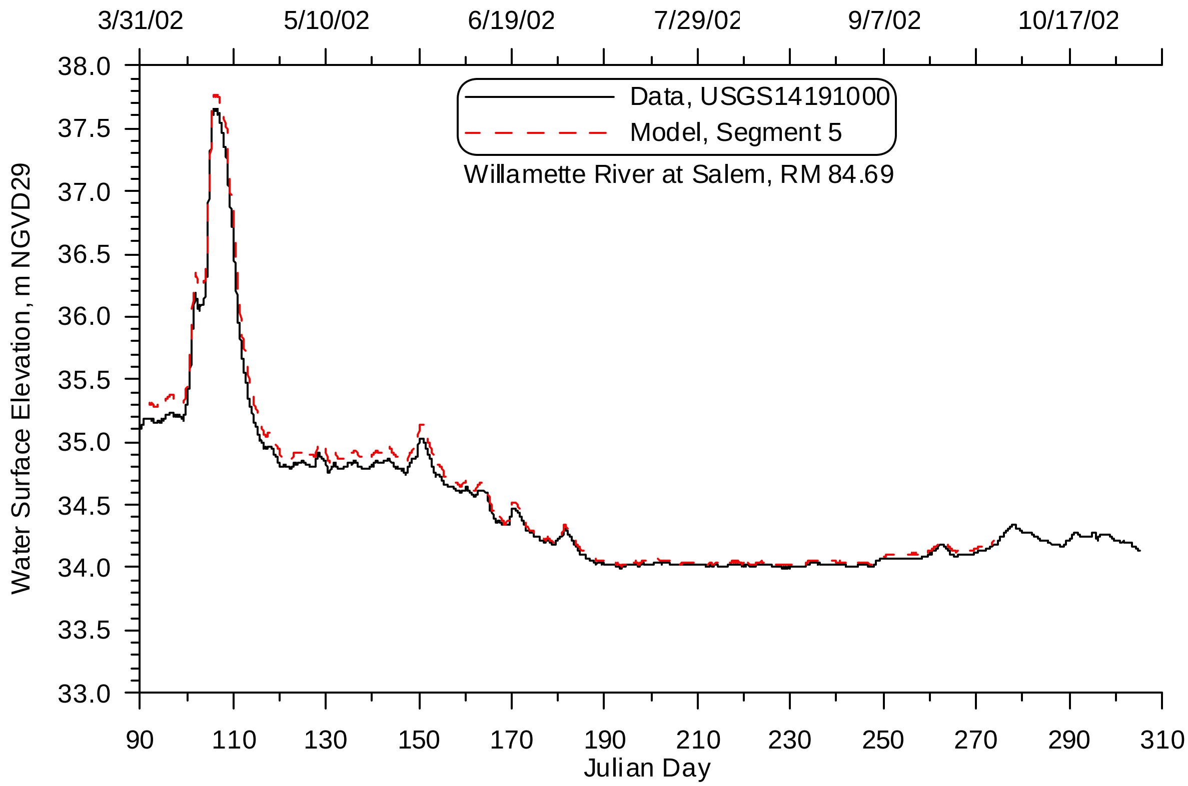

Figure 92: Willamette River at Salem model-data water level comparison, 2002

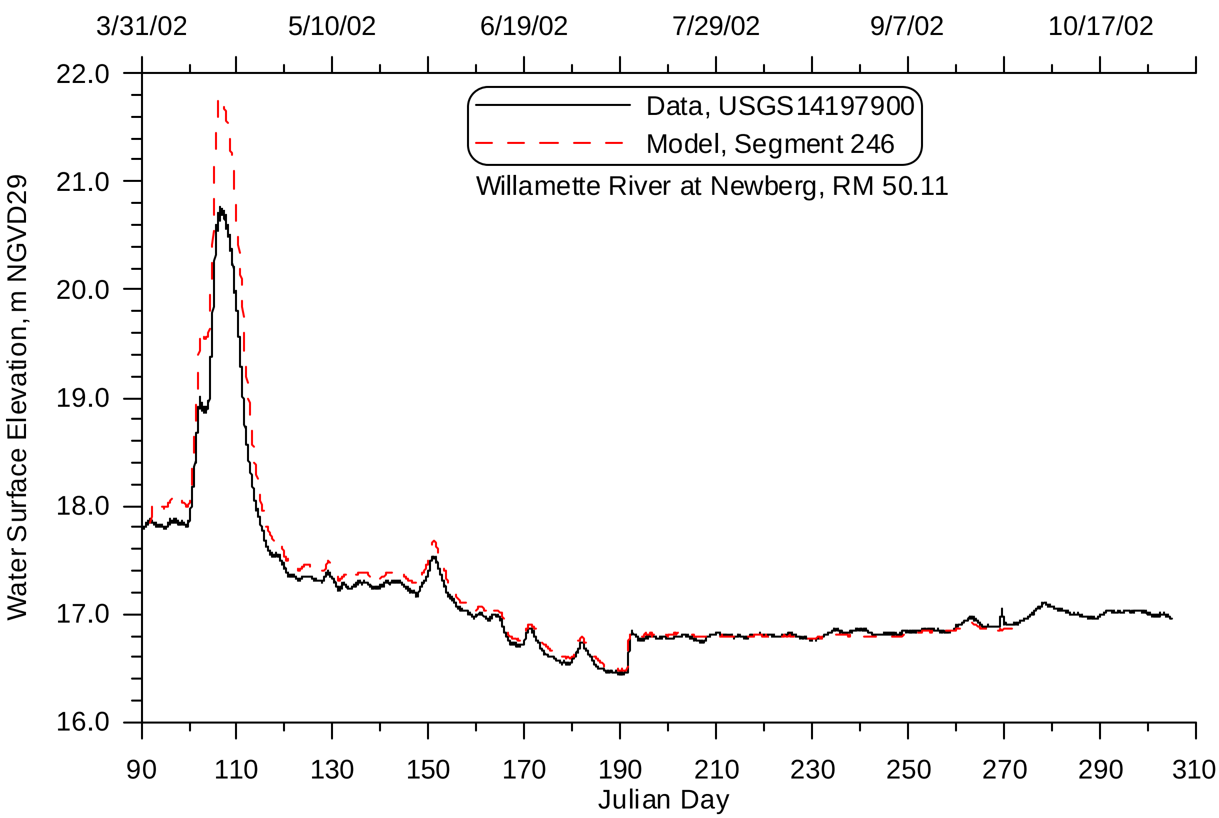

Figure 93: Willamette River at Newberg model-data water level comparison, 2002

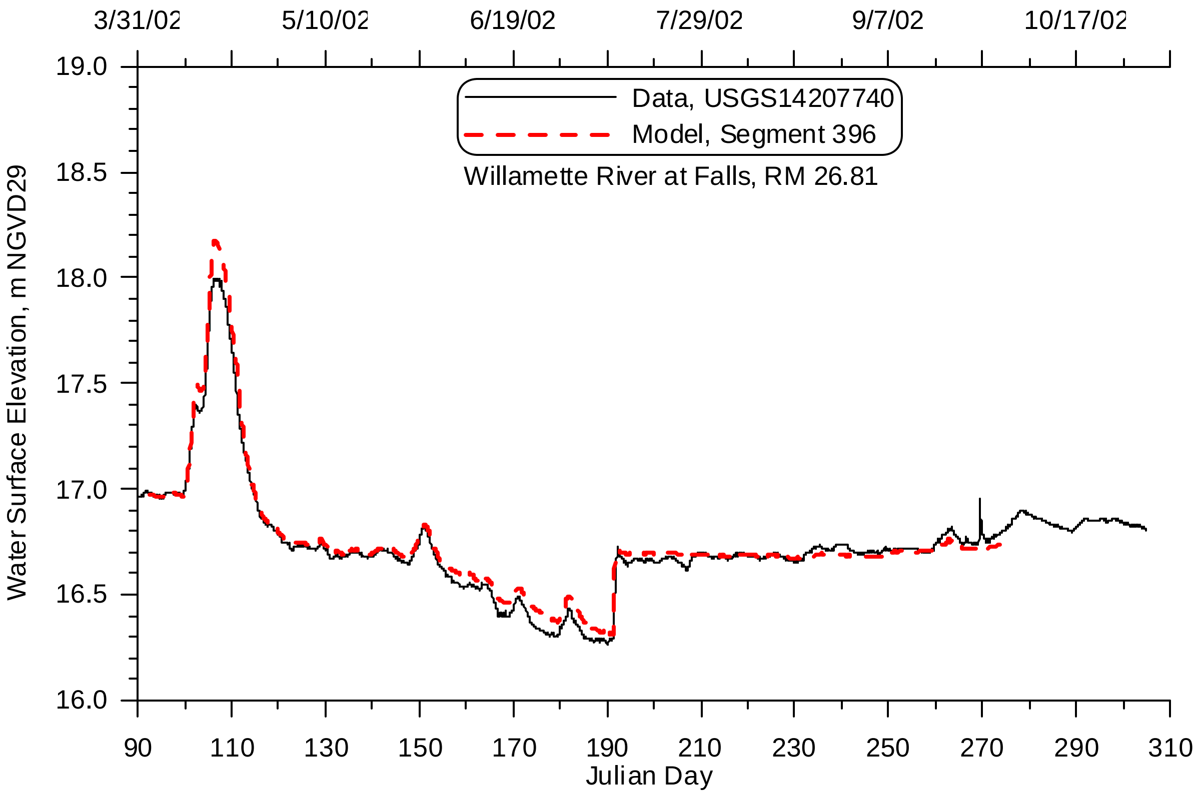

Figure 94: Willamette River at the Willamette Falls model-data water level comparison, 2002

Water Temperature

Water temperature was calibrated using continuous temperature data recorded every half hour or hour at several locations in the basin. Additionally model-data comparisons were made both at small time scales and at large time scales over the simulation period to ensure diurnal fluctuations were simulated accurately. Calibration parameters included adjusting the Manning's friction factor, channel widths, wind sheltering, evaporation, and sediment temperatures. Vegetative and topographic shade characteristics were not adjusted since the model input was developed using a detailed GIS analysis.

The Middle Willamette River basin has twenty sites where continuous temperatures were recorded in 2001 or 2002 for calibrating the model. Figure 95 shows a map of the basin with the gage site locations and Table 15 shows a list of the gage sites, their RM locations, and corresponding model segment.

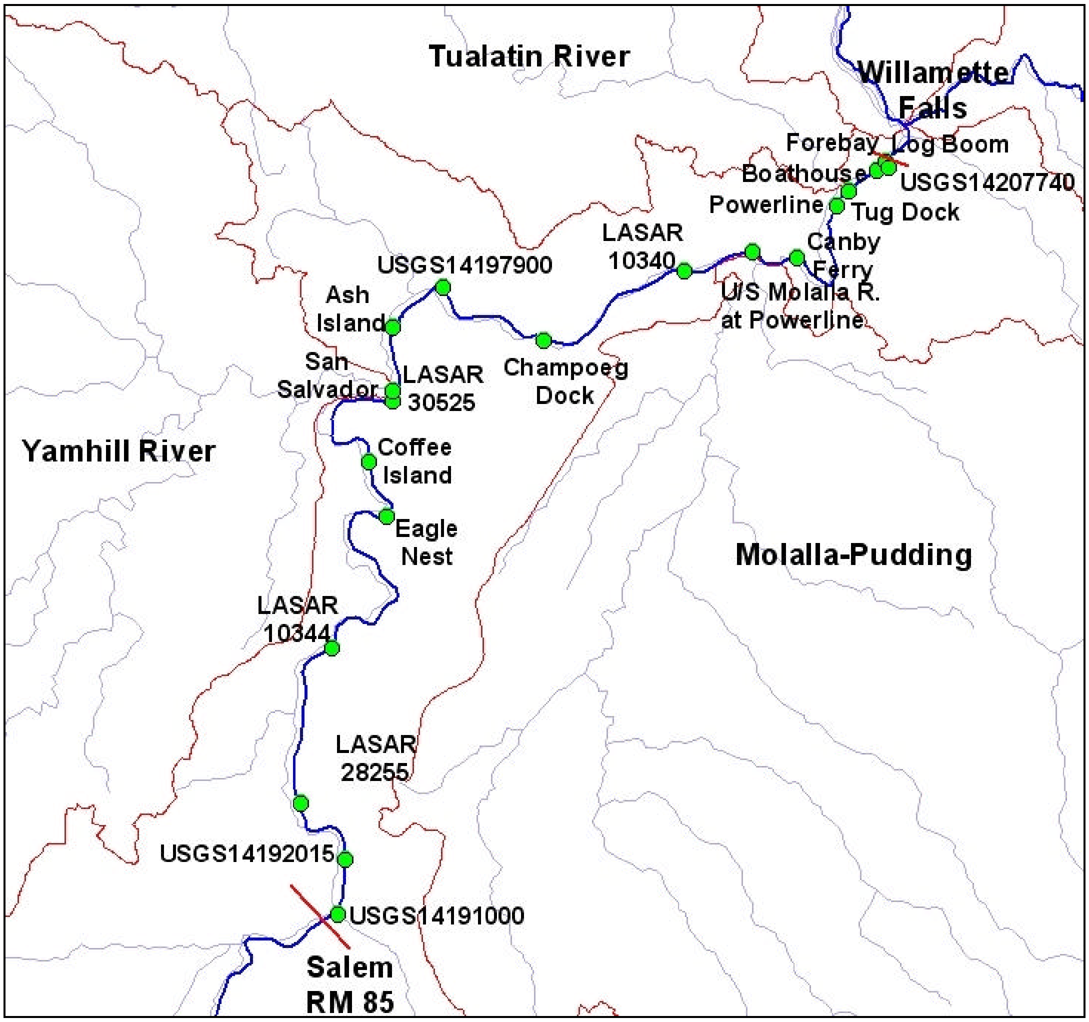

Figure 95: Middle Willamette River Temperature Calibration Site Locations

Table 15: Middle Willamette River Temperature Calibration Sites

Site ID	Site Description	RM	Model Segment
USGS 14191000	Willamette River at Salem, OR	85.66	5
USGS 14192015	Willamette River at Keizer, OR	82.60	18
LASAR 28255	Willamette River at Willow Lake treatment plant	79.18	40
LASAR 10344	Willamette River at Wheatland Ferry	72.63	82
PGE Eagle Nest A&B	Willamette River at Eagle Nest	63.95	140
PGE Coffee Island A&B / DEQ Coffee Island	Willamette River at Coffee Island	61.51	156
PGE San Salvador A&B	Willamette River at San Salvador Island	55.58	196
LASAR 30525	Willamette River upstream of Yamhill River	55.30	197
PGE Ash Island A&B	Willamette River above Ash Island (under Powerline)	52.76	228
USGS 14197900	Willamette River at Newberg, OR	50.11	246
PGE Champoeg Dock A&B	Willamette River at Champoeg Park	45.21	277
LASAR 10340	Willamette River at I5 Bridge, Wilsonville, OR	38.94	318

Site ID	Site Description	RM	Model Segment
PGE US Molalla R. A&B	Upstream of the mouth of Molalla River	36.17	336
PGE Canby A&B	Willamette River at Canby Ferry	34.32	348
PGE Powerline A&B	Willamette River at Powerline crossing	29.37	380
USGS 14207740	Willamette River at Willamette Falls	28.81	396
PGE Tug Dock A&B	Willamette River at Tug Dock	28.61	384
PGE Boathouse A&B	Willamette River at Boathouse	27.27	393
PGE Forebay A&B	Powerhouse Forebay, above Willamette Falls	26.81	396
PGE Log Boom A&B	Willamette River at PGE Project Log Boom	26.81	396

The model was calibrated by comparing the continuous temperature data and model results but since the model will be used for running model scenarios examining the daily maximum temperature model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

Of particular importance in calibrating for temperature was adjusting Manning friction coefficient. The Manning's value affected travel time, which controls the amount of heating or cooling a given parcel of water would undergo as it passed through the Middle Willamette River. Model-data error statistics for the 2001 Middle Willamette River model's continuous water temperature predictions are listed in Table 16. Figure 96 through Figure 125 show model-data plots of continuous water temperature. Although there are some gaps in the data at several site, the time series comparison plots shows the model is doing well in matching both diurnal temperature swings and 10-14 weather patterns seen in air temperature and water temperature elsewhere in the basin. Model-data error statistics were all less than 0.85 ^{o}C during 2001.

Table 16: Middle Willamette River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14191000	85.66	5	253	0.01	0.05	0.07
USGS 14192015	82.60	18	2839	0.32	0.47	0.56
LASAR 28255	79.18	40	2951	0.68	0.70	0.81
LASAR 10344	72.63	82	1596	0.56	0.61	0.69
PGE Eagle Nest A	63.95	140	1596	0.37	0.50	0.60
PGE Eagle Nest B	63.95	140	1596	0.32	0.48	0.57
PGE Coffee Island A	61.51	156	1595	0.05	0.55	0.66
PGE Coffee Island B	61.51	156	1596	0.17	0.56	0.67
PGE San Salvador A	55.58	196	1596	0.14	0.49	0.60
PGE San Salvador B	55.58	196	1596	0.14	0.49	0.60
PGE Ash Island A	52.76	228	1596	0.08	0.50	0.63
PGE Ash Island B	52.76	228	1596	-0.07	0.51	0.63
PGE Champoeg Dock A	45.21	277	1596	-0.19	0.45	0.55

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
PGE Champoeg Dock B	45.21	277	1596	-0.10	0.44	0.53
LASAR 10340	38.94	318	3192	-0.42	0.50	0.62
PGE US Molalla R. A	36.17	336	1577	-0.39	0.53	0.66
PGE US Molalla R. B	36.17	336	1596	-0.31	0.50	0.62
PGE Canby A	34.32	348	1596	-0.14	0.41	0.49
PGE Canby B	34.32	348	1596	0.04	0.41	0.48
PGE Powerline A	29.37	380	1596	-0.14	0.42	0.51
PGE Powerline B	29.37	380	1596	-0.02	0.41	0.49
PGE Tug Dock A	28.61	384	1596	0.11	0.40	0.47
PGE Tug Dock B	28.61	384	1596	-0.17	0.40	0.48
PGE Boathouse A	27.27	393	1596	-0.23	0.41	0.50
PGE Boathouse B	27.27	393	1596	-0.21	0.41	0.50
PGE Forebay A	26.81	396	1564	-0.02	0.43	0.51
PGE Forebay B	26.81	396	1565	0.15	0.43	0.53
PGE Log Boom A	26.81	396	1596	-0.04	0.44	0.53
PGE Log Boom B	26.81	396	1240	0.10	0.42	0.52
USGS 14207740	28.81	396	2544	0.00	0.42	0.50

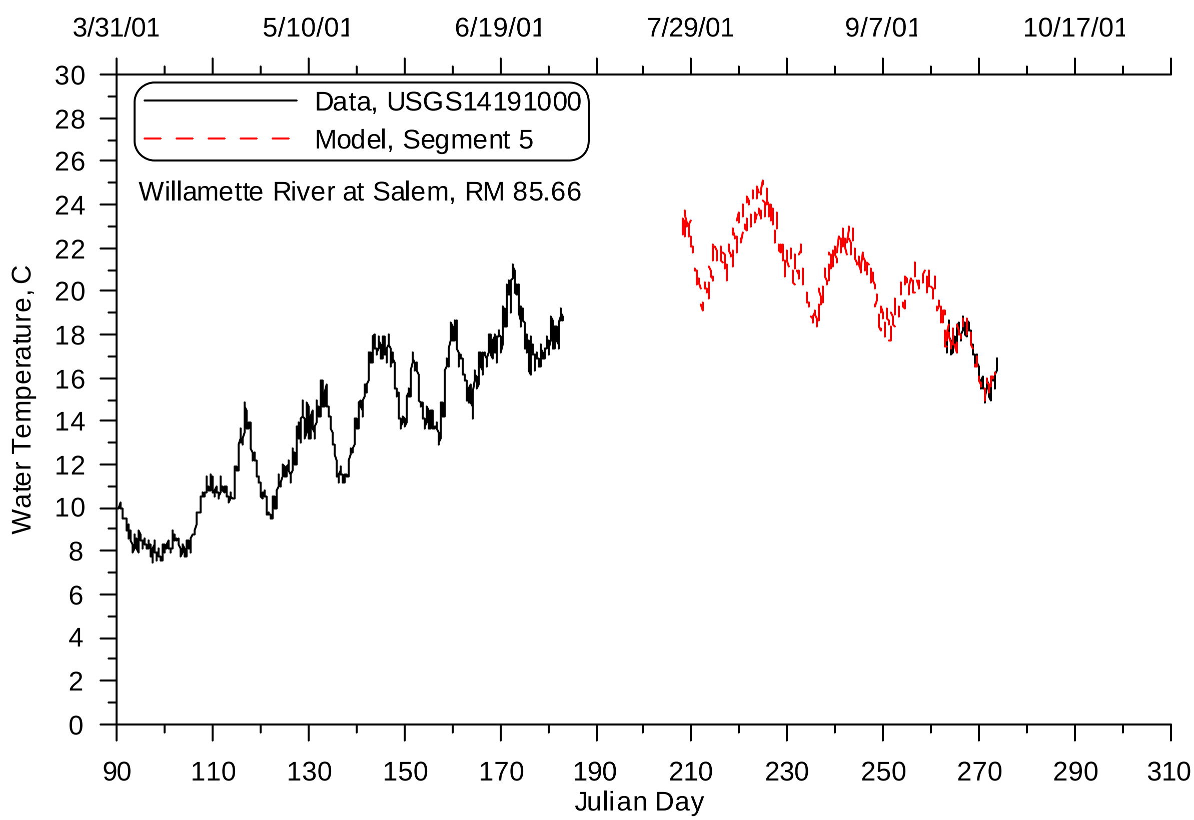

Figure 96: Willamette River at Salem model-data continuous temperature comparison, 2001

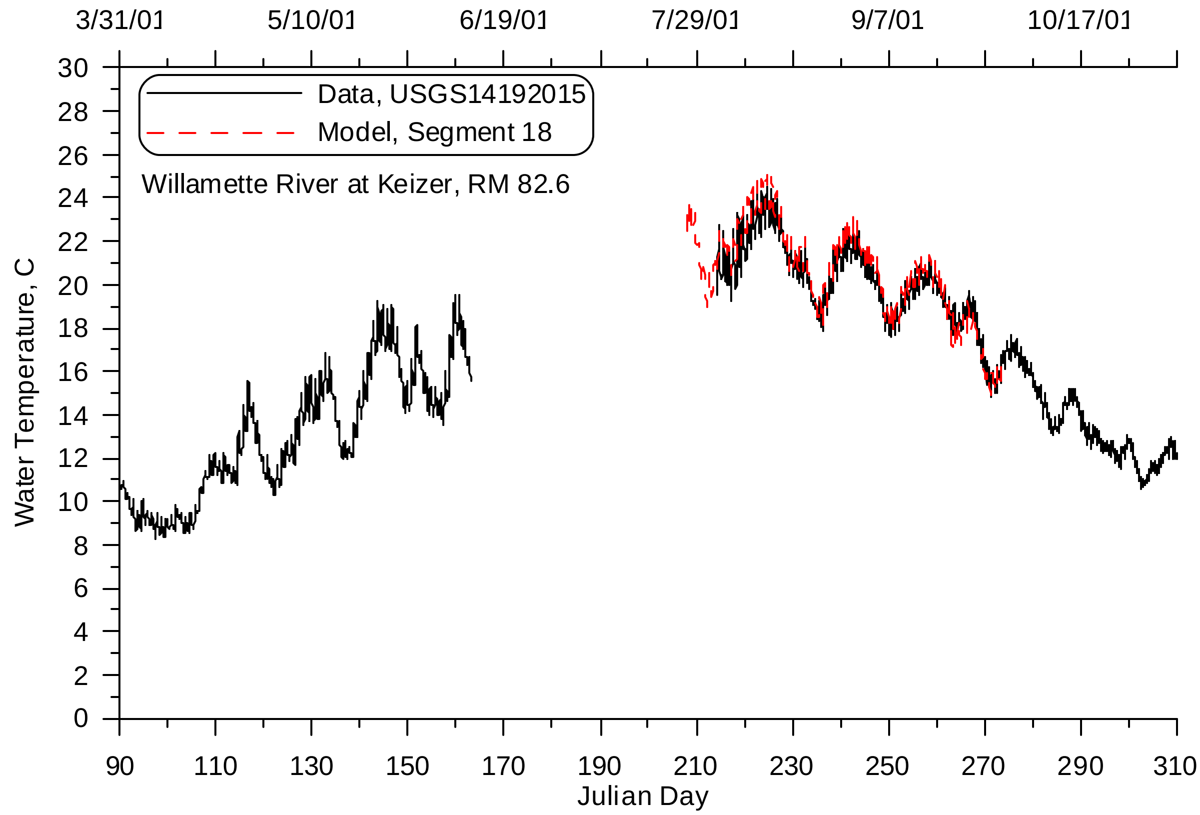

Figure 97: Willamette River at Keizer model-data continuous temperature comparison, 2001

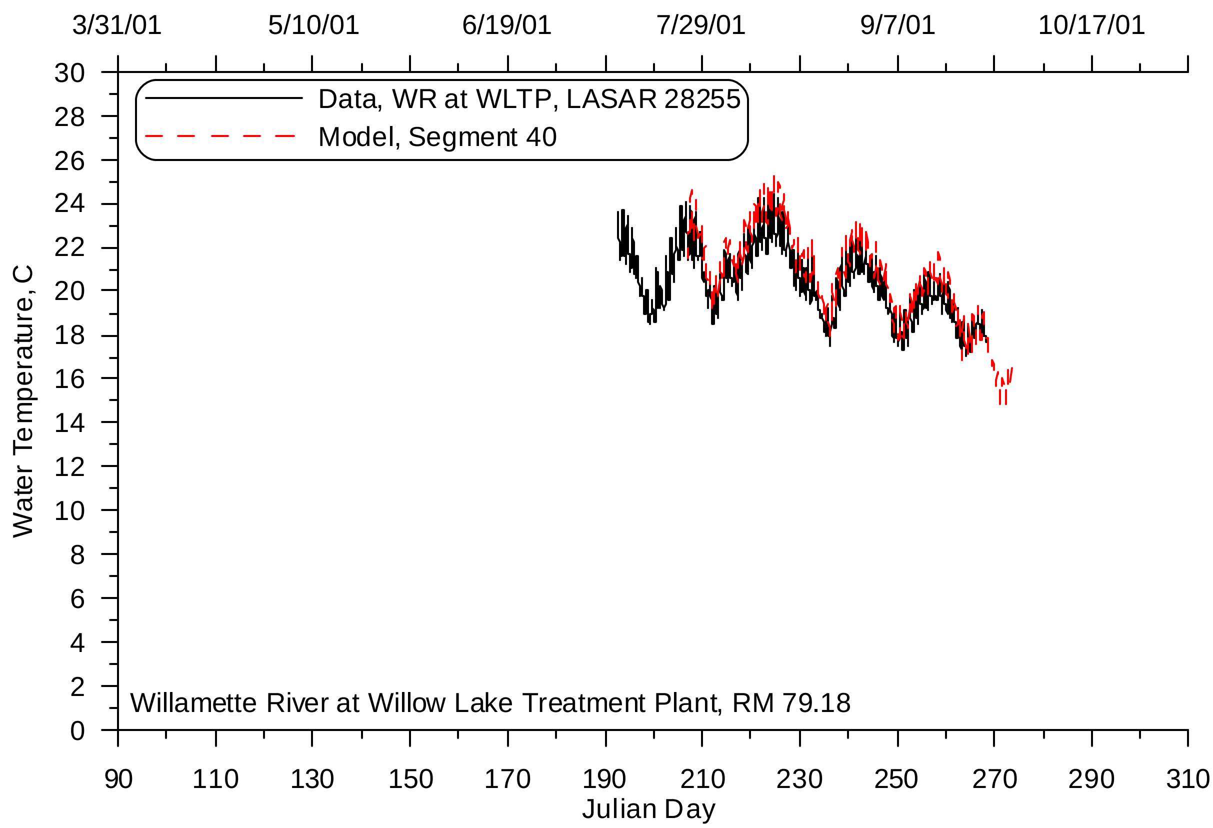

Figure 98: Willamette River at Willow Lake Treatment Plant model-data continuous temperature comparison, 2001

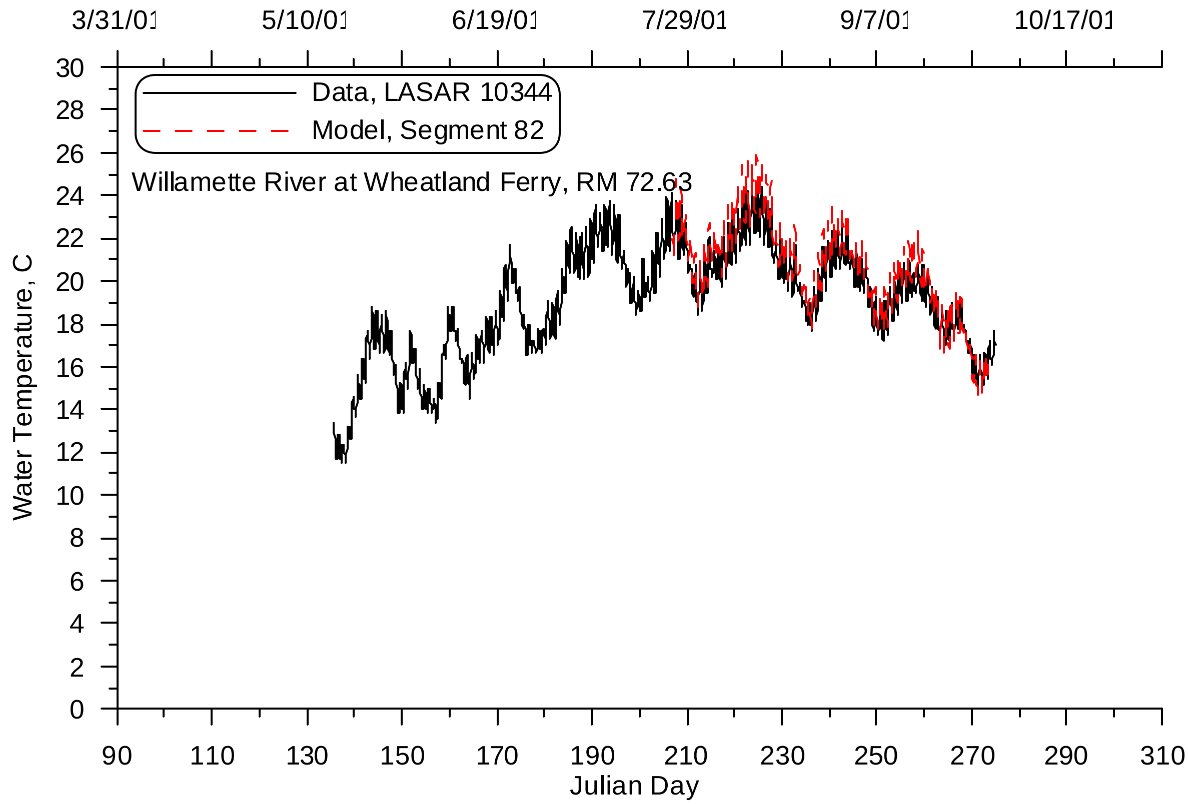

Figure 99: Willamette River at Wheatland Ferry model-data continuous temperature comparison, 2001

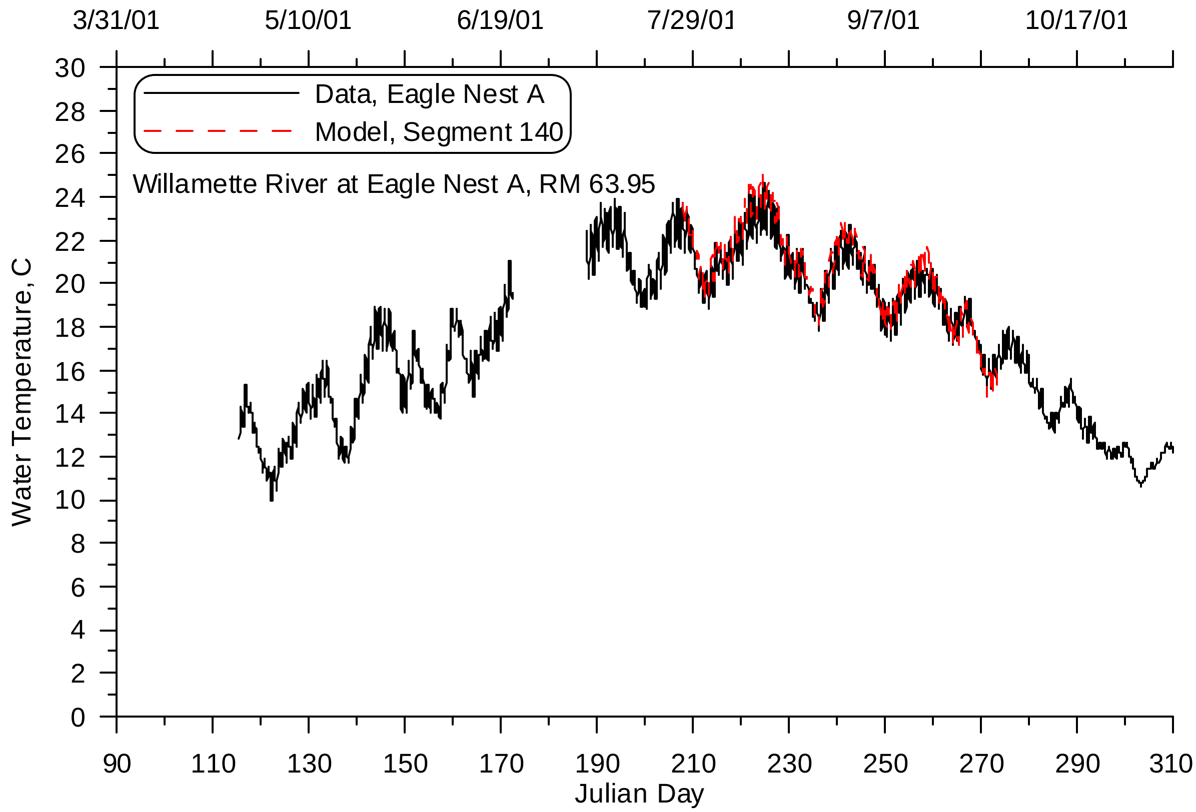

Figure 100: Willamette River at Eagle Nest A model-data continuous temperature comparison, 2001

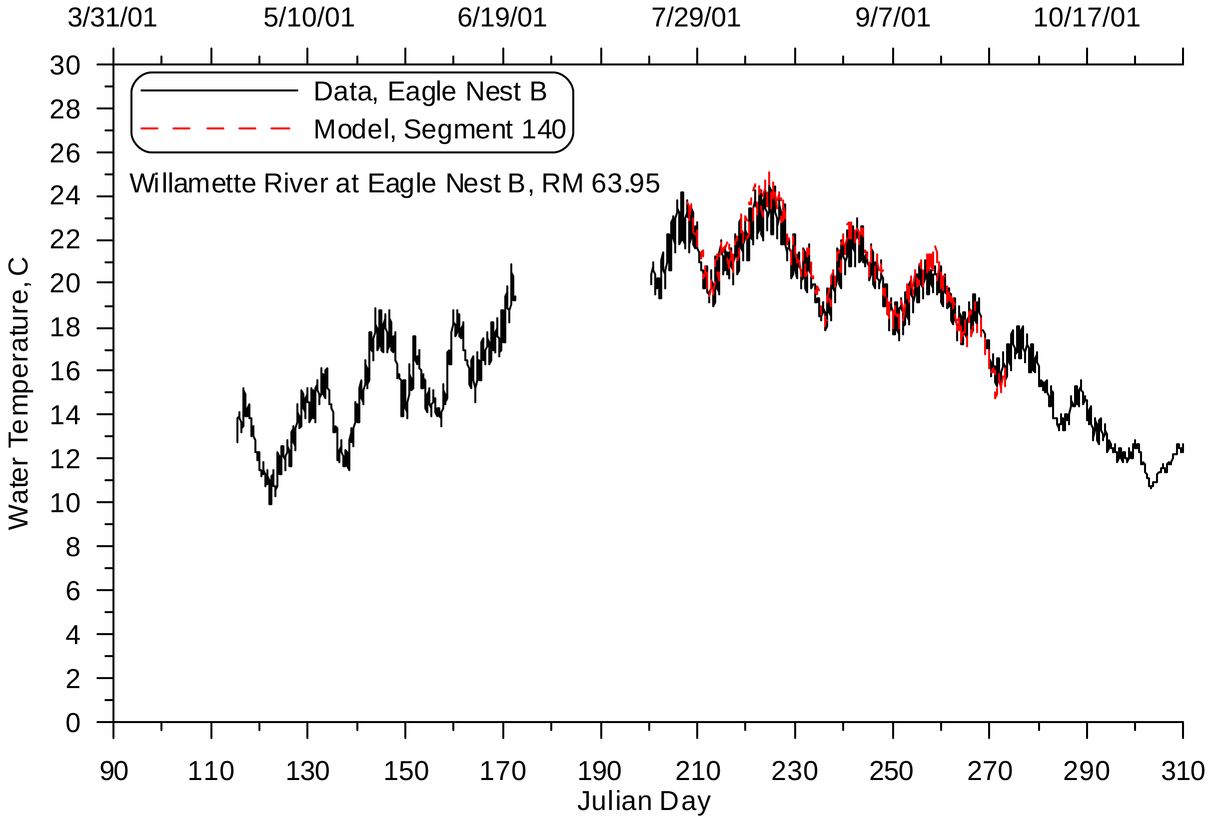

Figure 101: Willamette River at Eagle Nest B model-data continuous temperature comparison, 2001

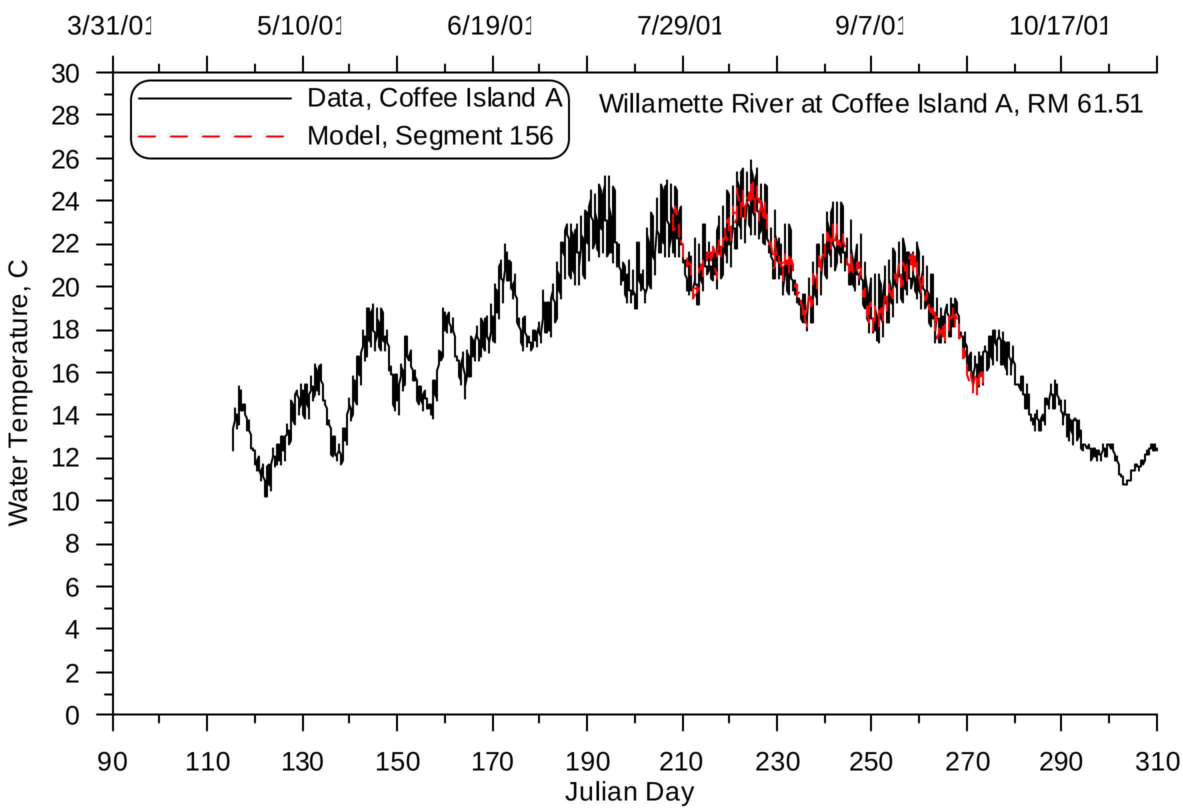

Figure 102: Willamette River at Coffee Island A model-data continuous temperature comparison, 2001

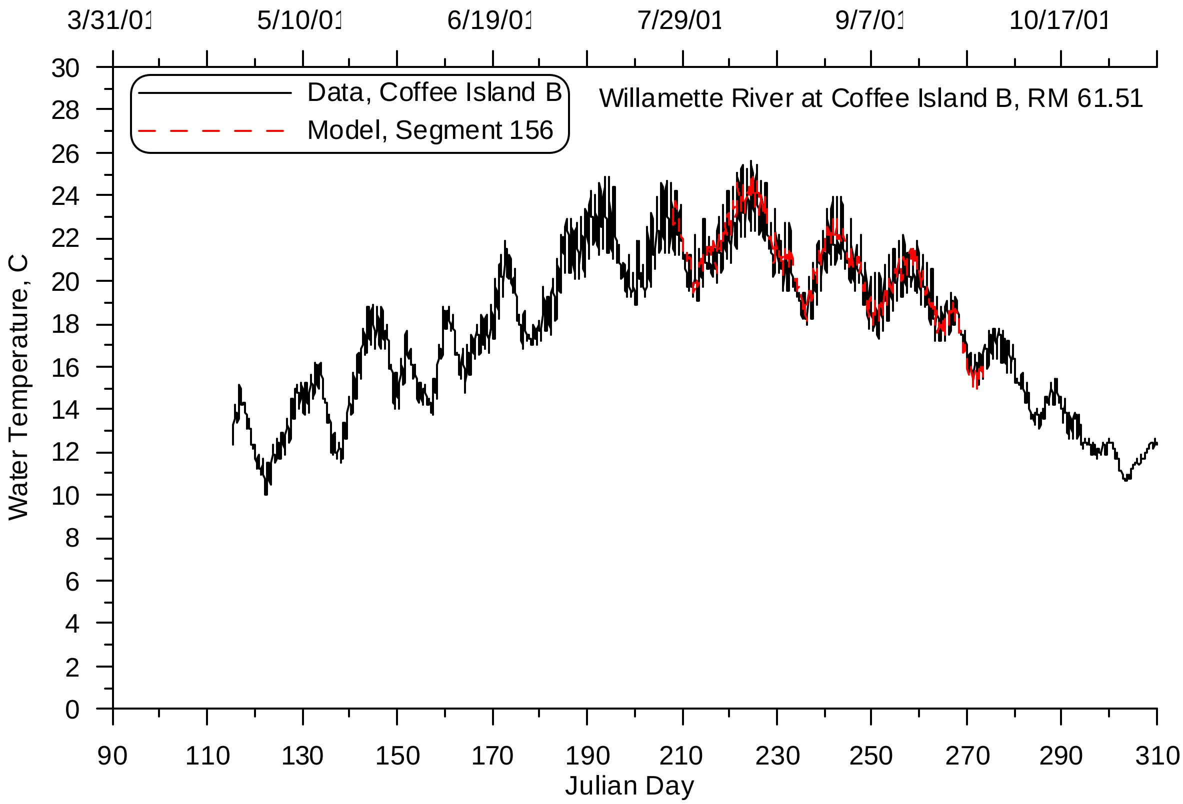

Figure 103: Willamette River at Coffee Island B model-data continuous temperature comparison, 2001

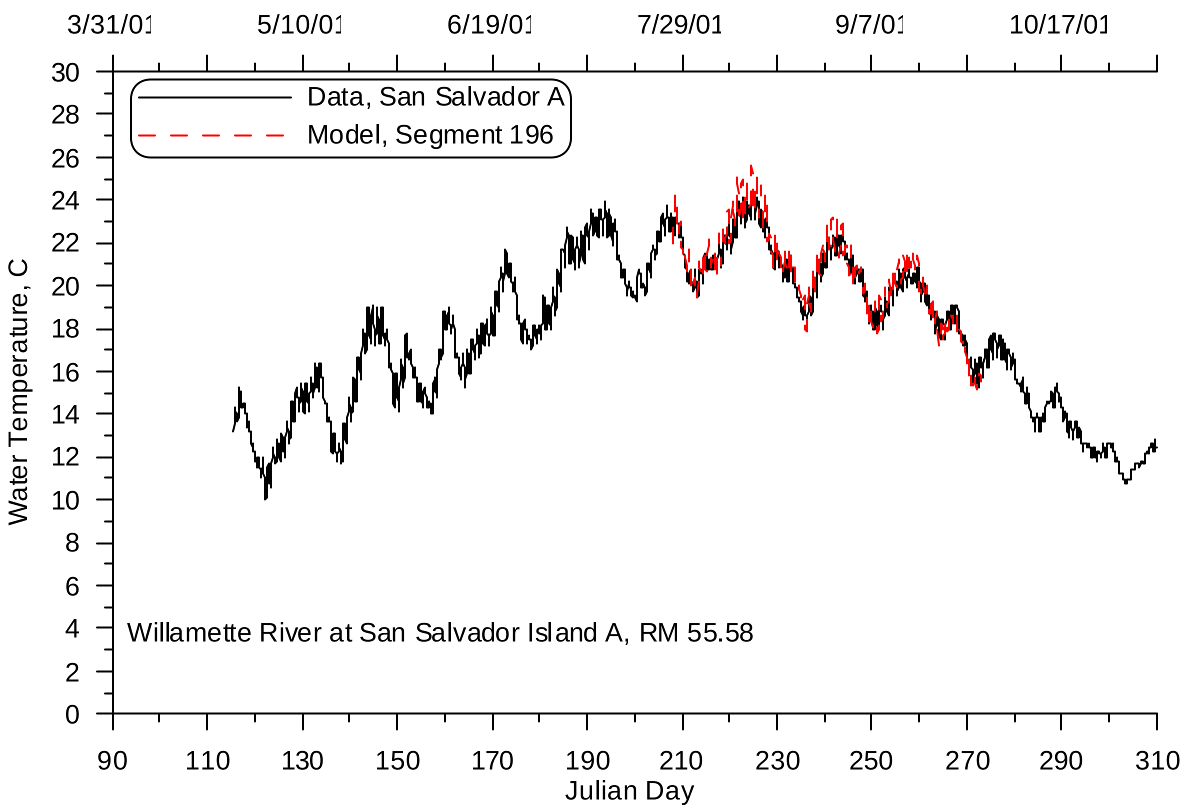

Figure 104: Willamette River at San Salvador A model-data continuous temperature comparison, 2001

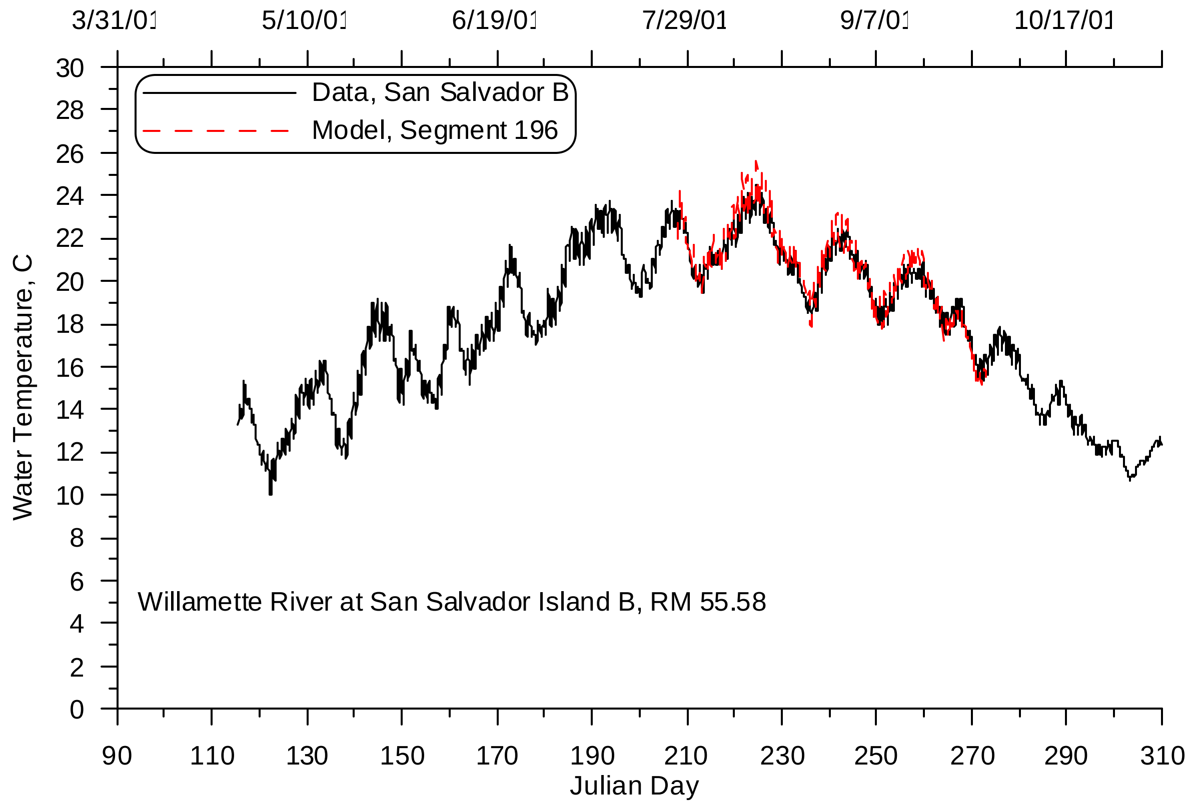

Figure 105: Willamette River at San Salvador B model-data continuous temperature comparison, 2001

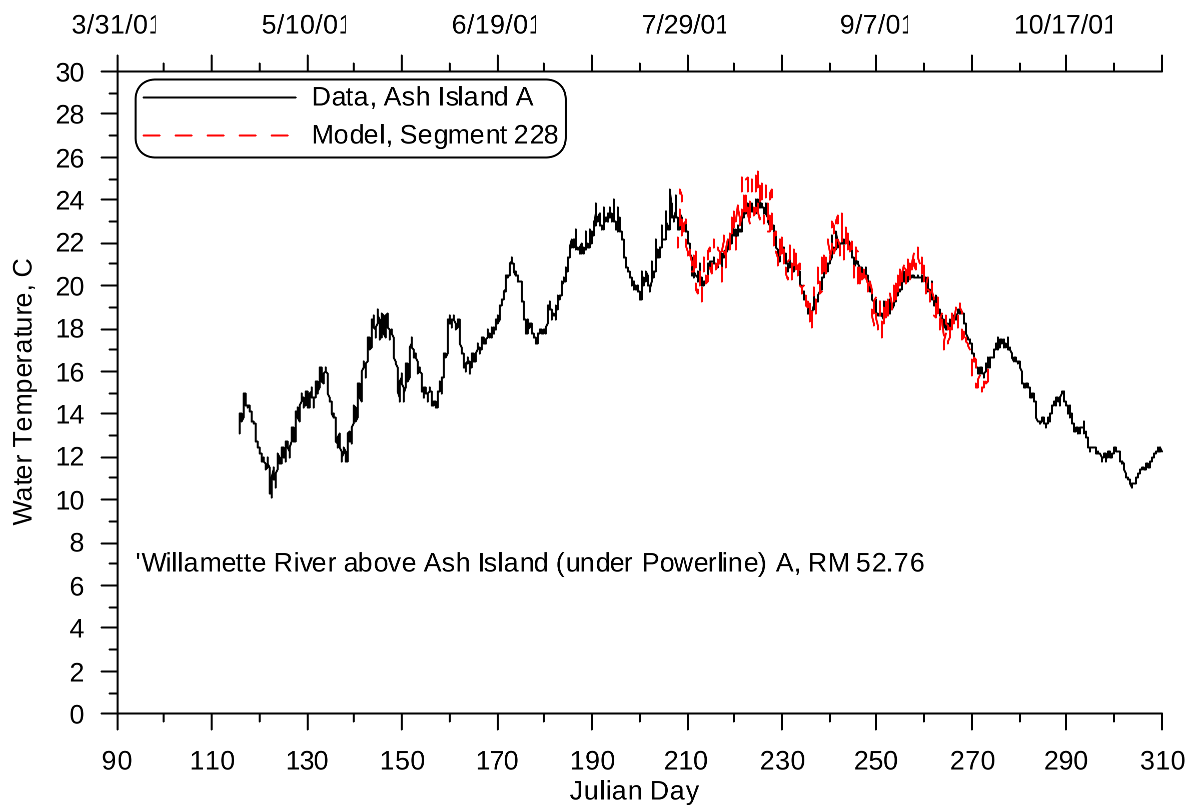

Figure 106: Willamette River above Ash Island A model-data continuous temperature comparison, 2001

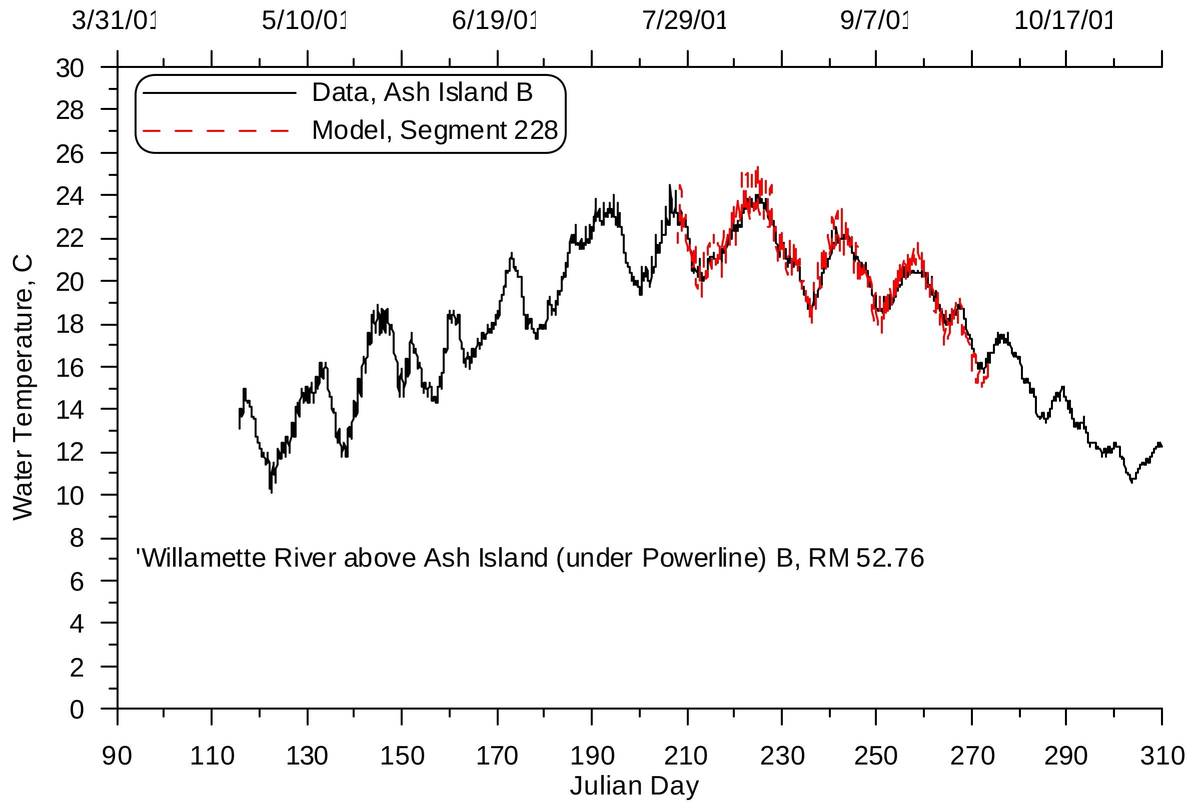

Figure 107: Willamette River above Ash Island B model-data continuous temperature comparison, 2001

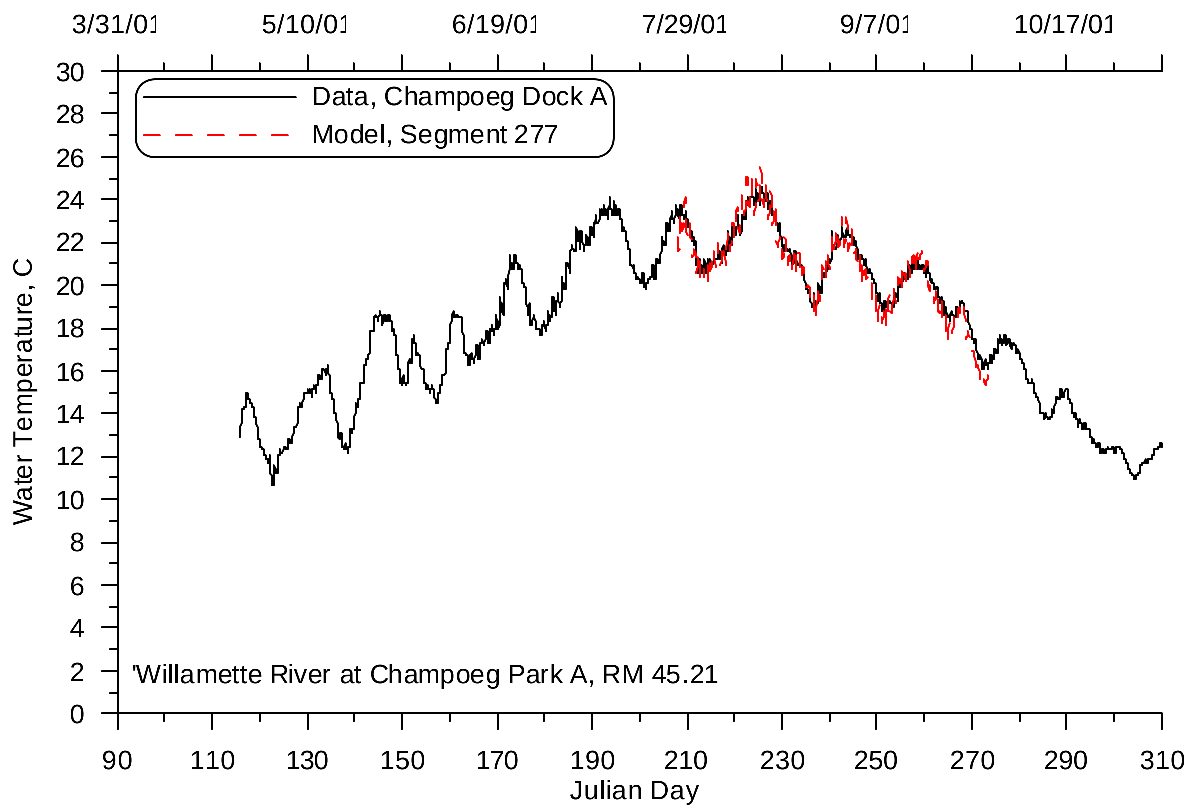

Figure 108: Willamette River at Champoeg Park A model-data continuous temperature comparison, 2001

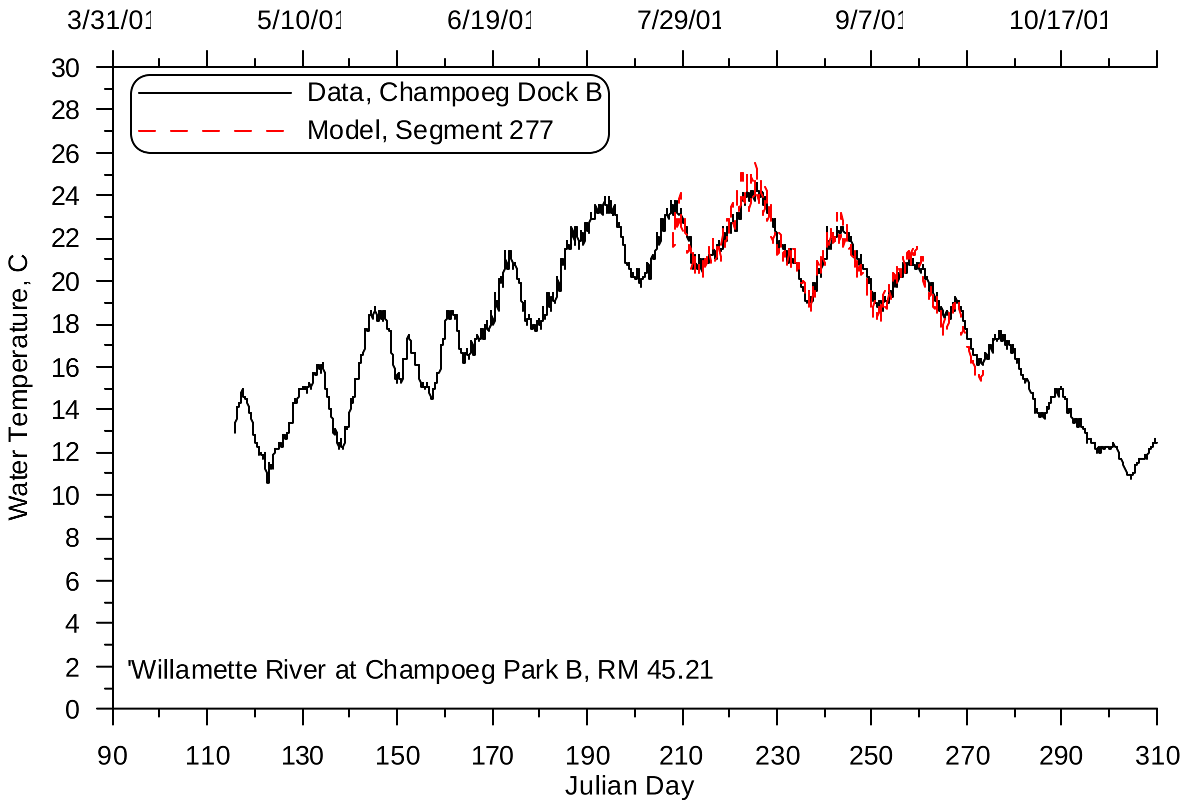

Figure 109: Willamette River at Champoeg Park B model-data continuous temperature comparison, 2001

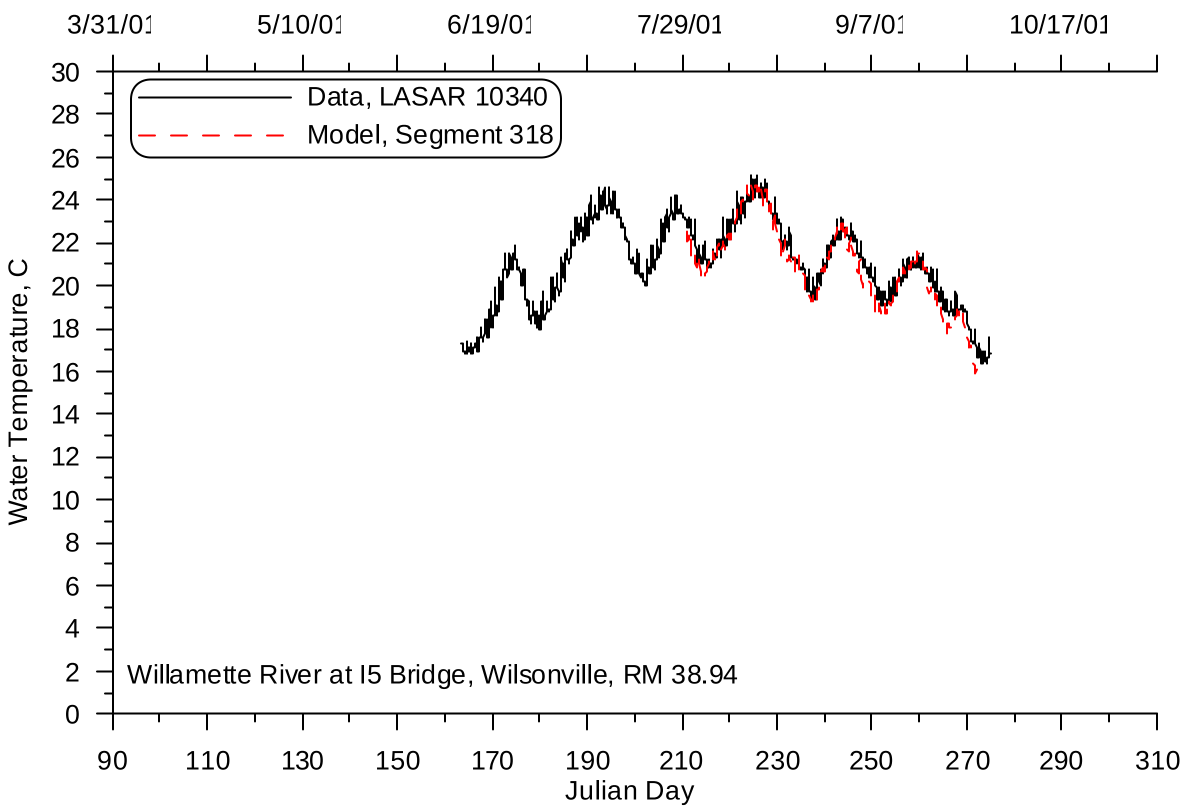

Figure 110: Willamette River at I5 Bridge, Wilsonville model-data continuous temperature comparison, 2001

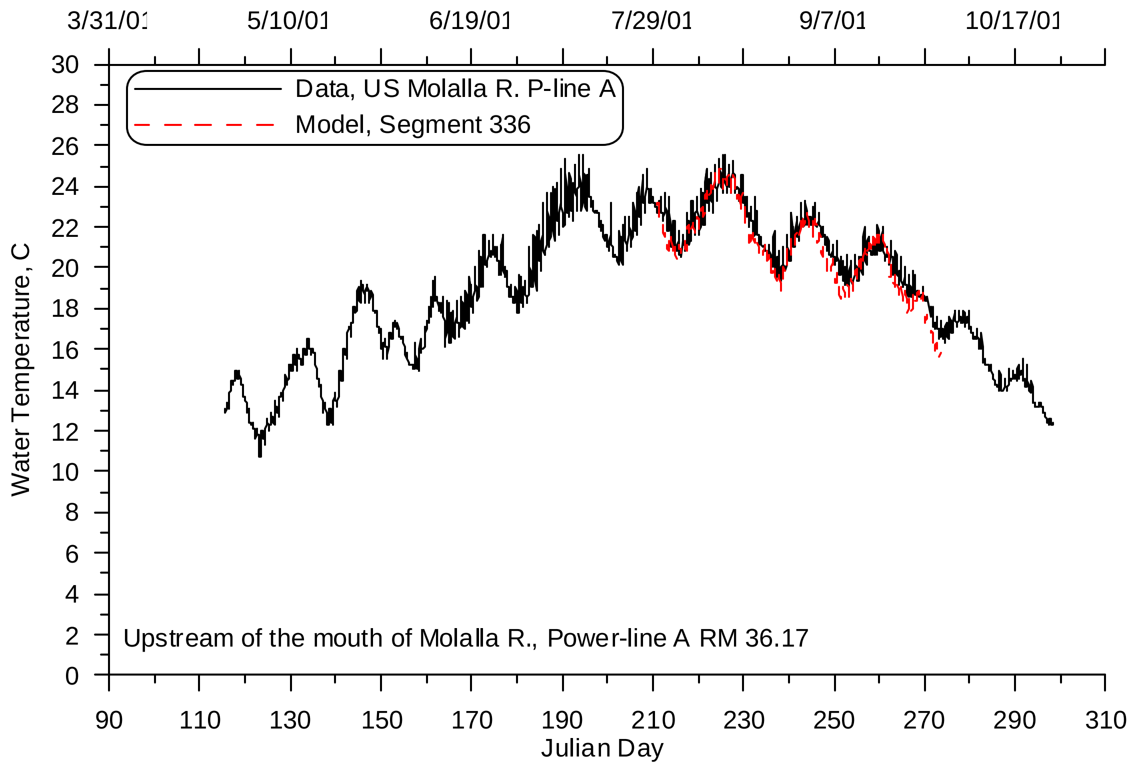

Figure 111: Willamette River upstream of the Molalla River confluence, Power-line A model-data continuous temperature comparison, 2001.

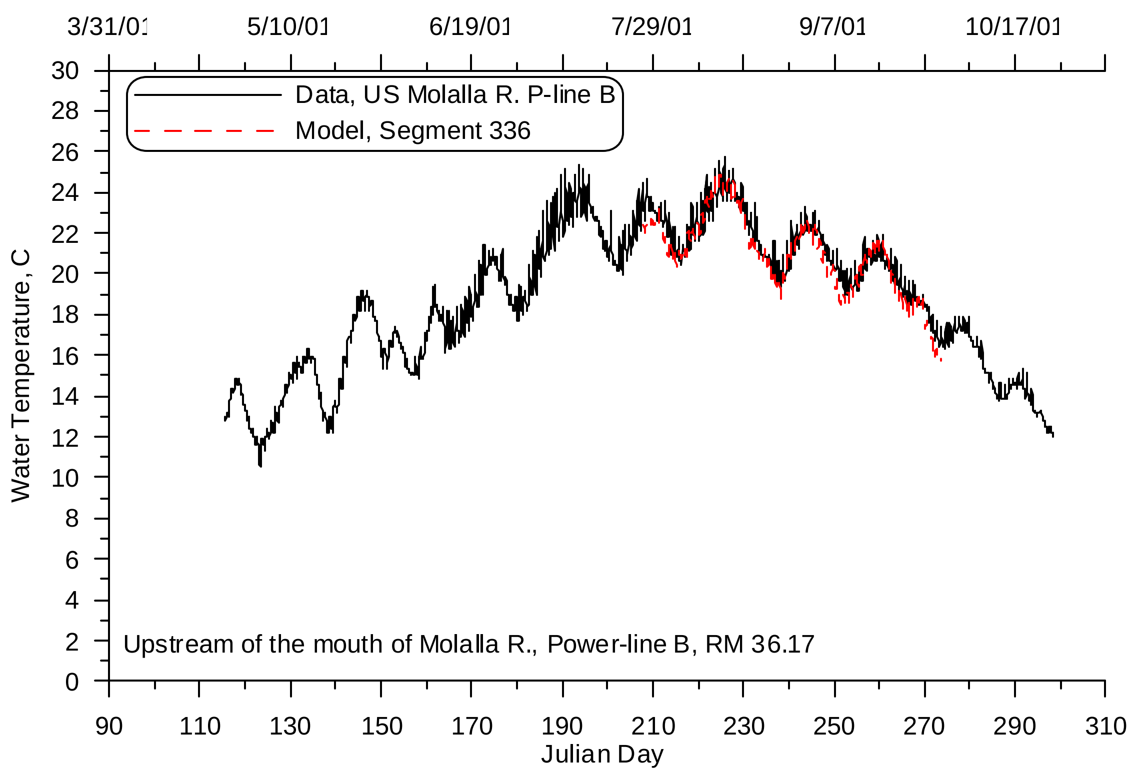

Figure 112: Willamette River upstream of the Molalla River confluence, Power-line B model-data continuous temperature comparison, 2001.

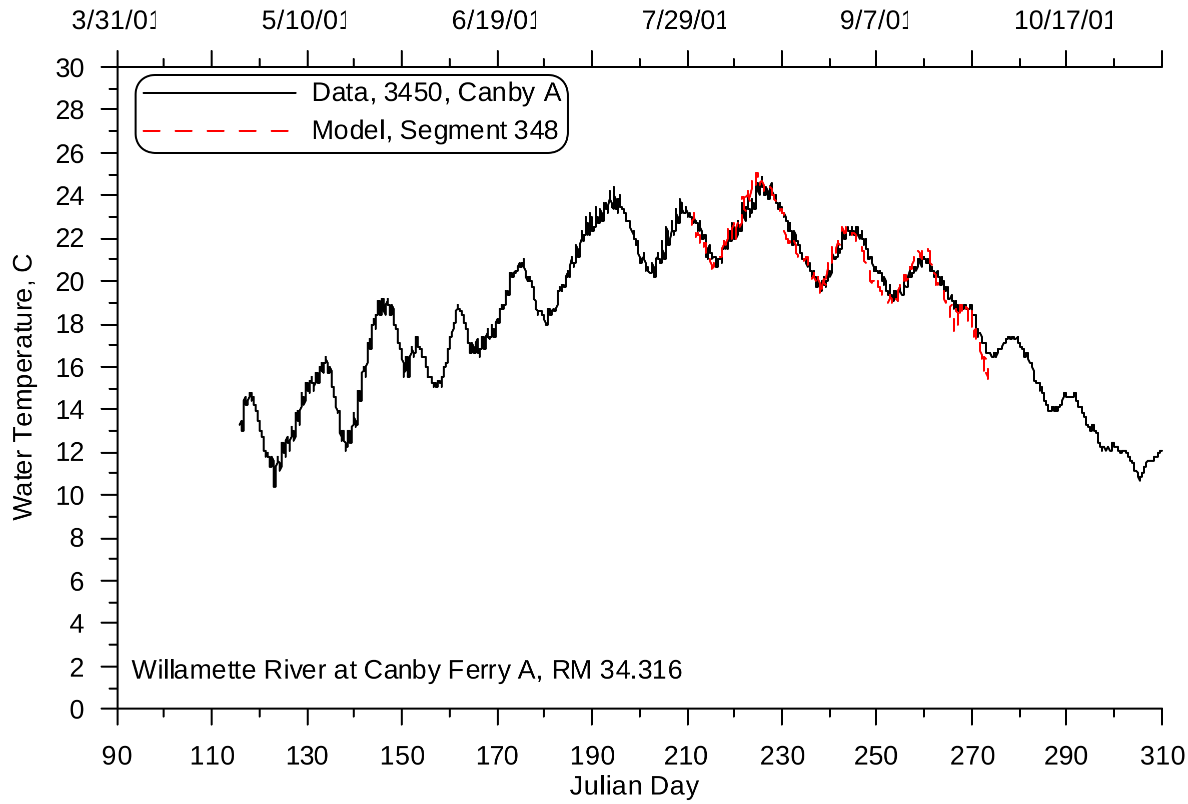

Figure 113: Willamette River at Canby Ferry A model-data continuous temperature comparison, 2001.

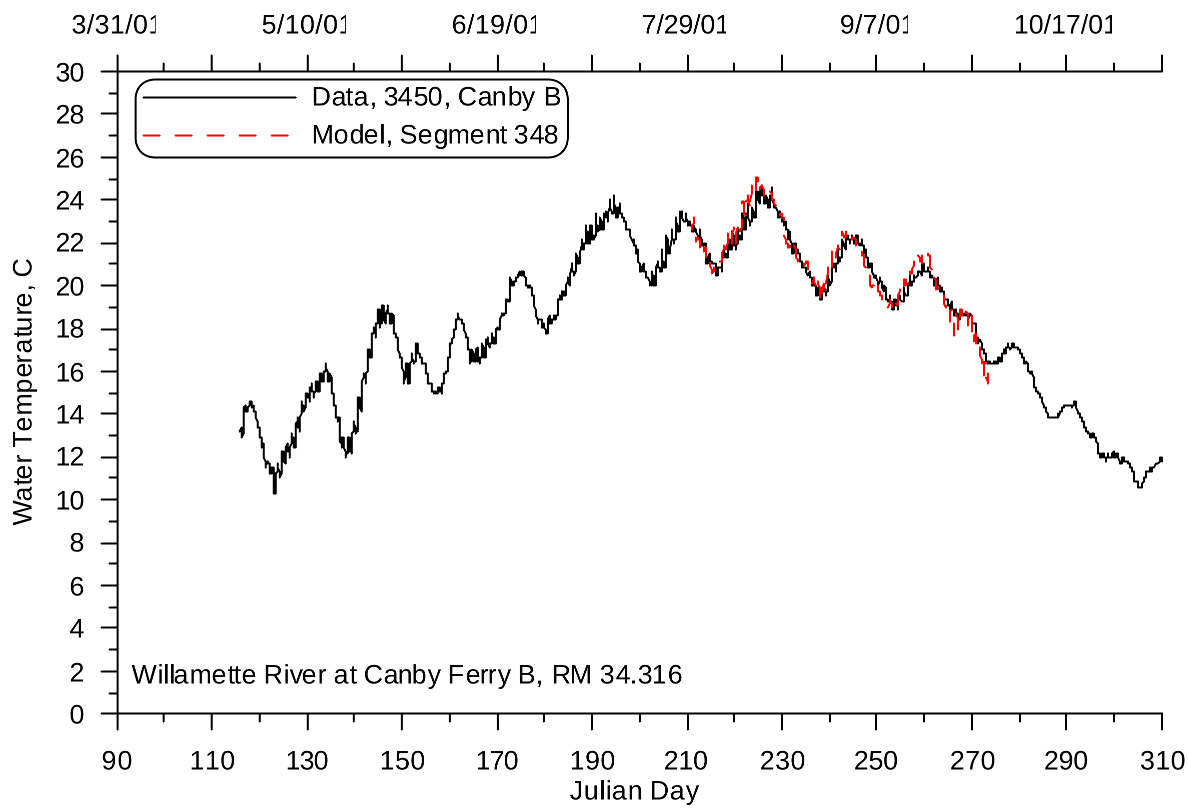

Figure 114: Willamette River at Canby Ferry B model-data continuous temperature comparison, 2001.

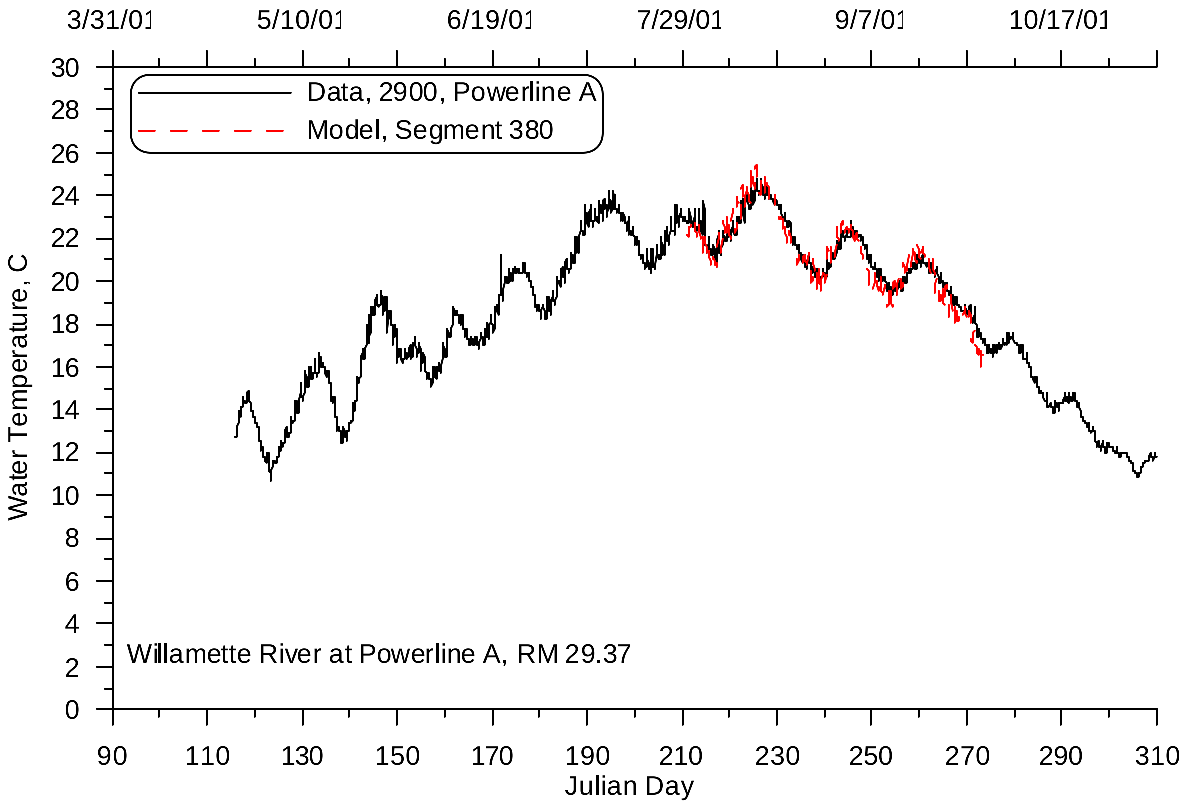

Figure 115: Willamette River at Powerline A model-data continuous temperature comparison, 2001

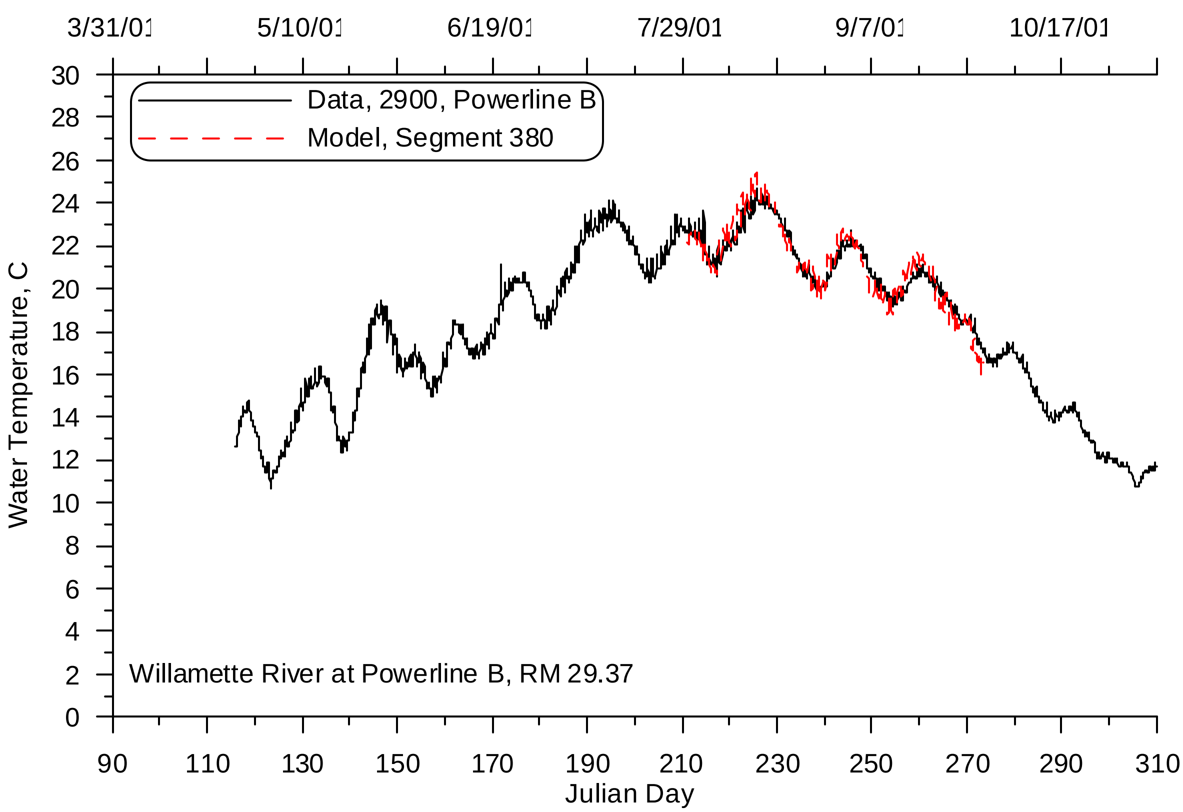

Figure 116: Willamette River at Powerline B model-data continuous temperature comparison, 2001

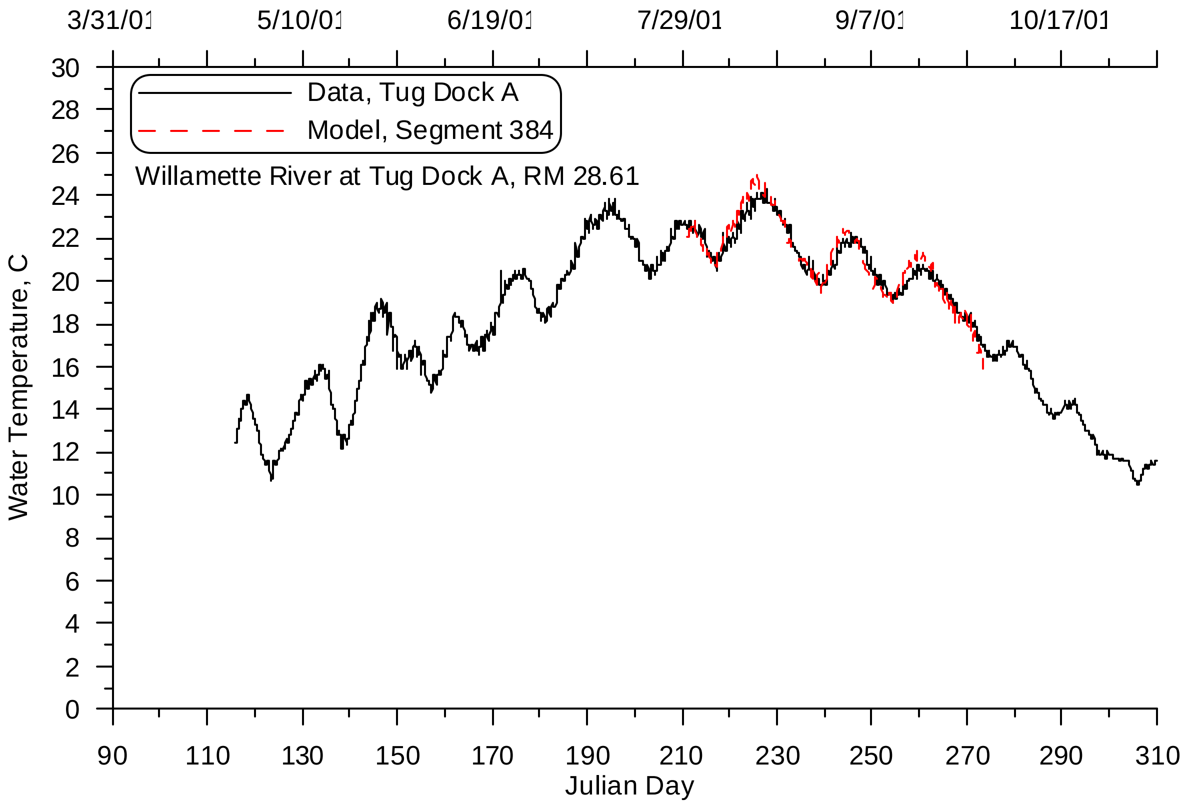

Figure 117: Willamette River at Tug Dock A model-data continuous temperature comparison, 2001

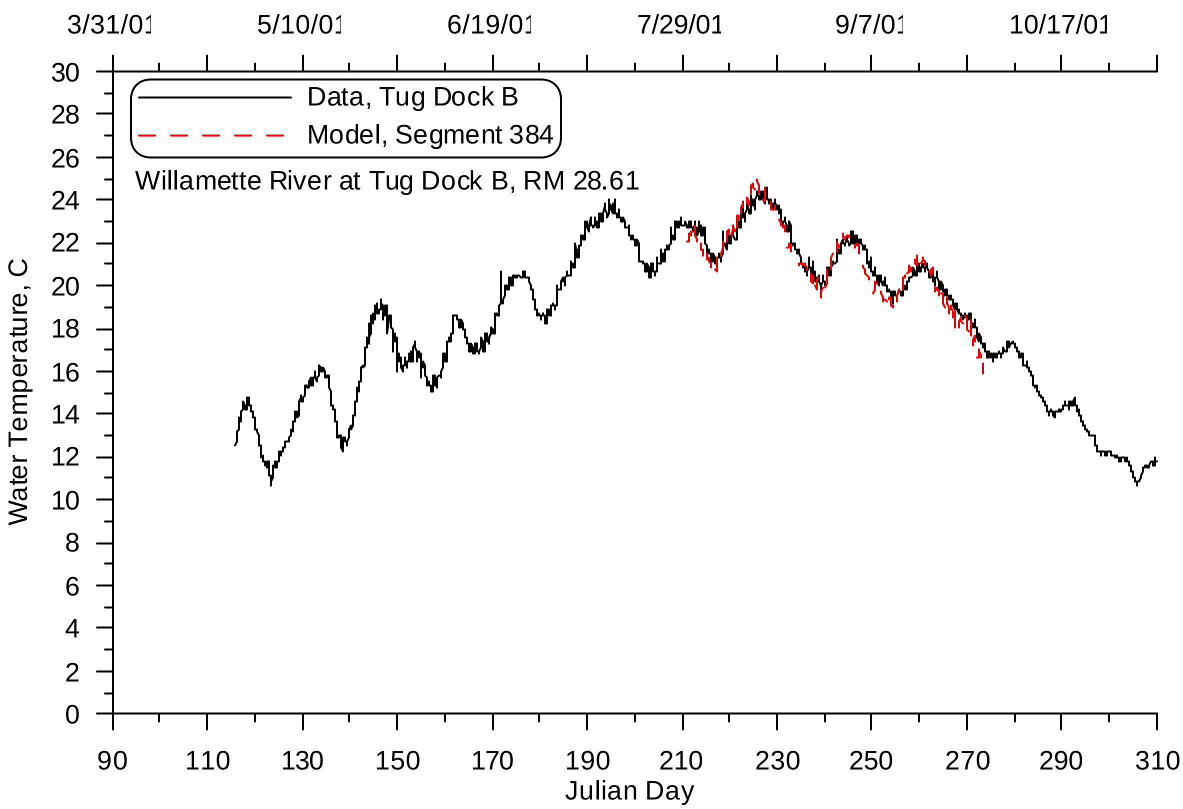

Figure 118: Willamette River at Tug Dock B model-data continuous temperature comparison, 2001

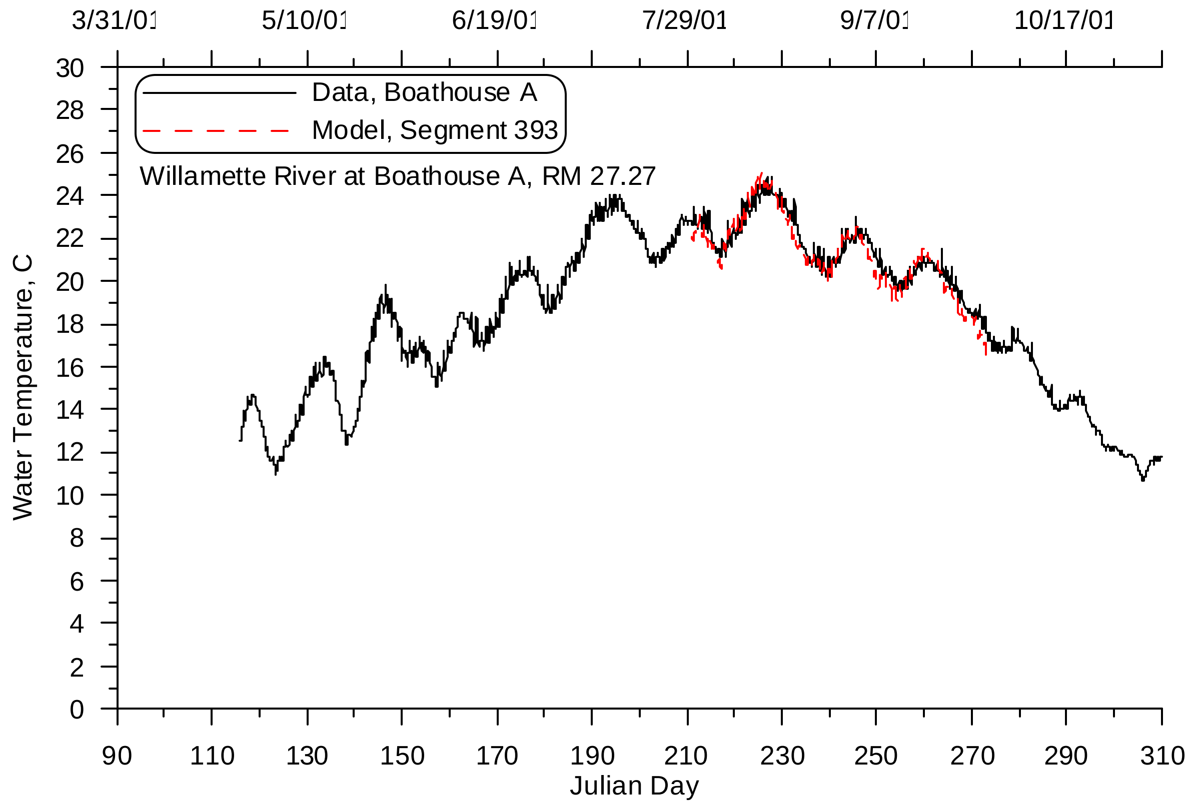

Figure 119: Willamette River at Boathouse A model-data continuous temperature comparison, 2001

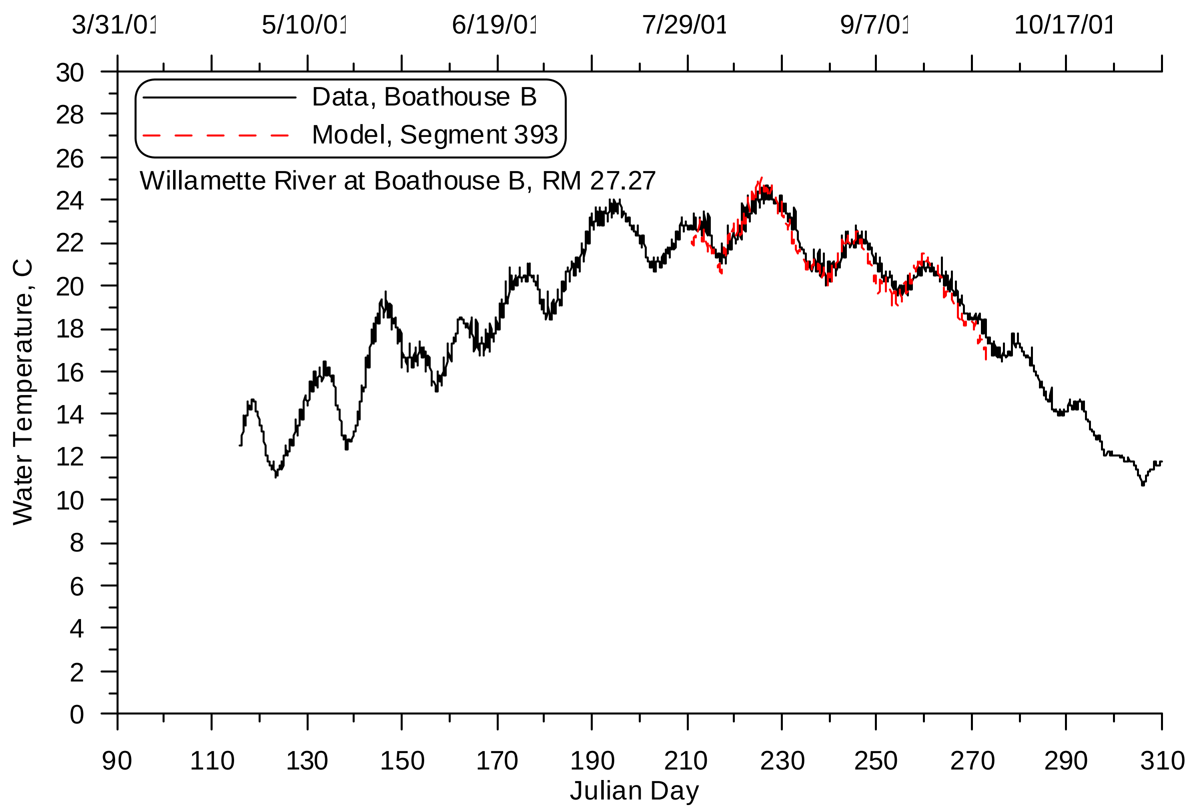

Figure 120: Willamette River at Boathouse B model-data continuous temperature comparison, 2001

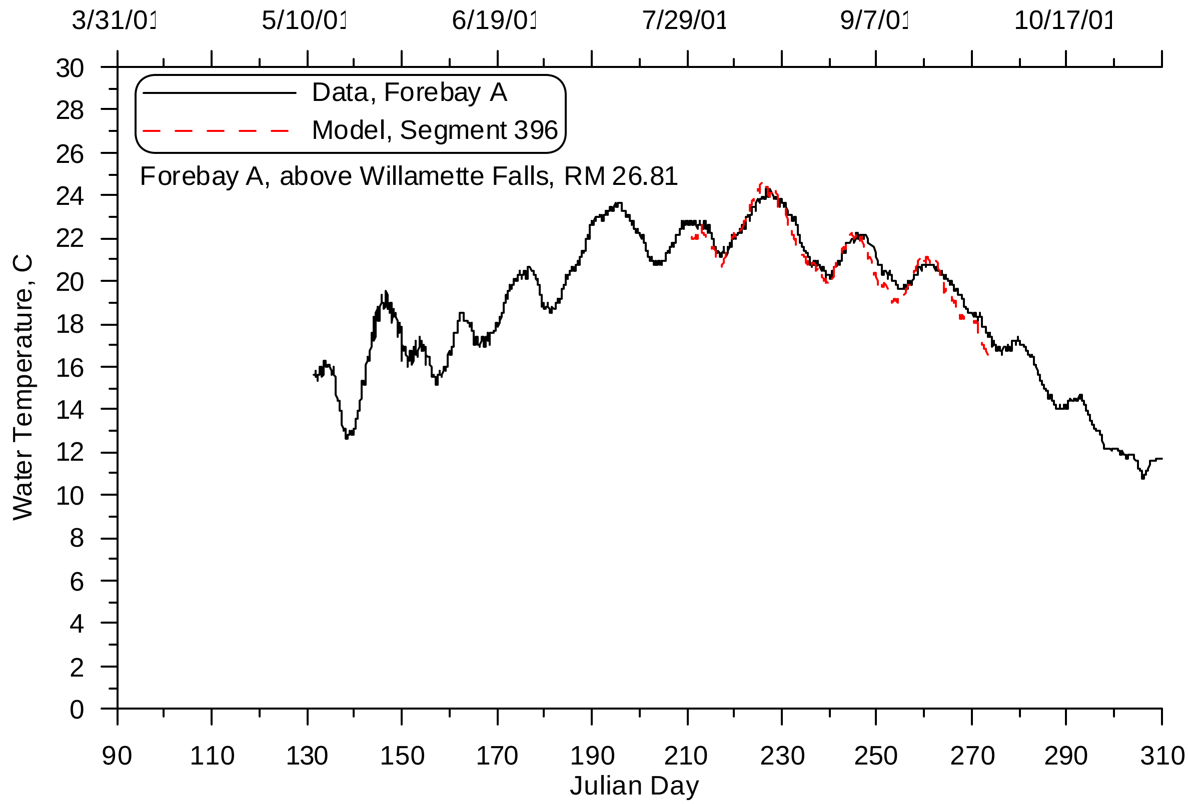

Figure 121: Willamette River at Forebay A model-data continuous temperature comparison, 2001

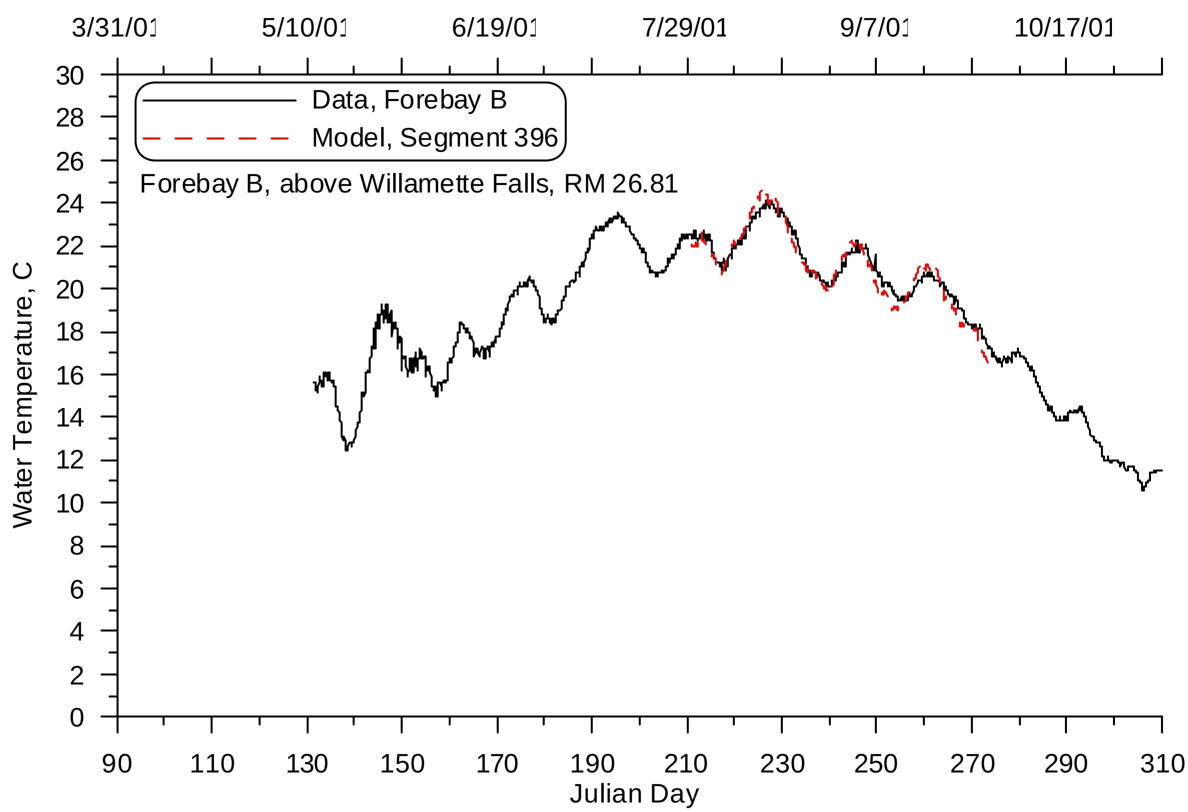

Figure 122: Willamette River at Forebay B model-data continuous temperature comparison, 2001

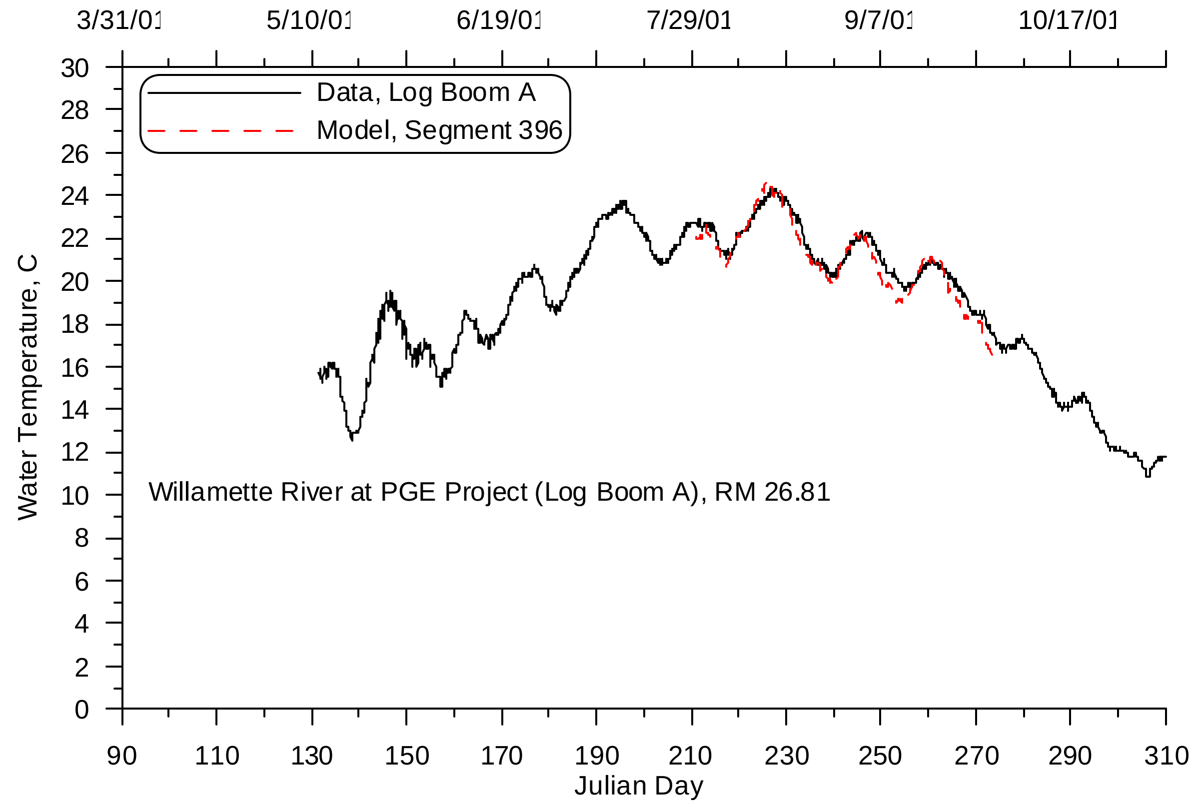

Figure 123: Willamette River at Log Boom A model-data continuous temperature comparison, 2001

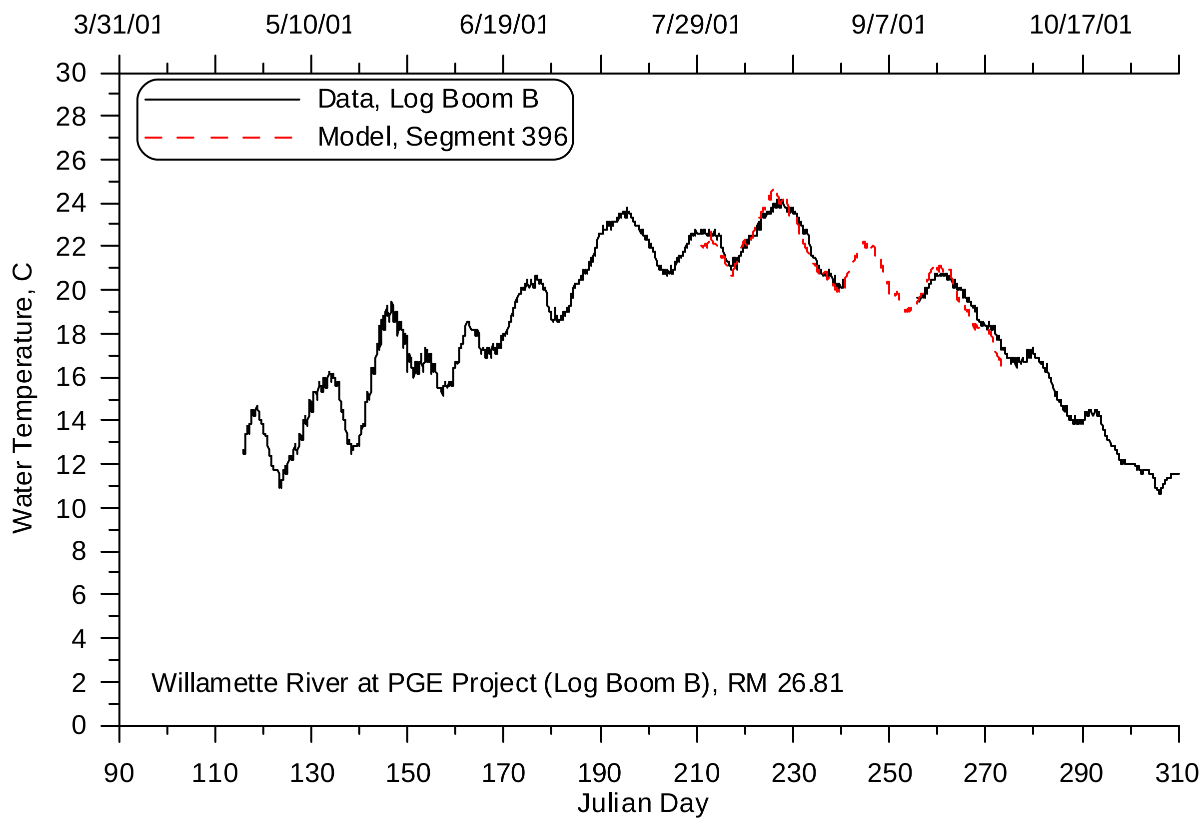

Figure 124: Willamette River at Log Boom B model-data continuous temperature comparison, 2001

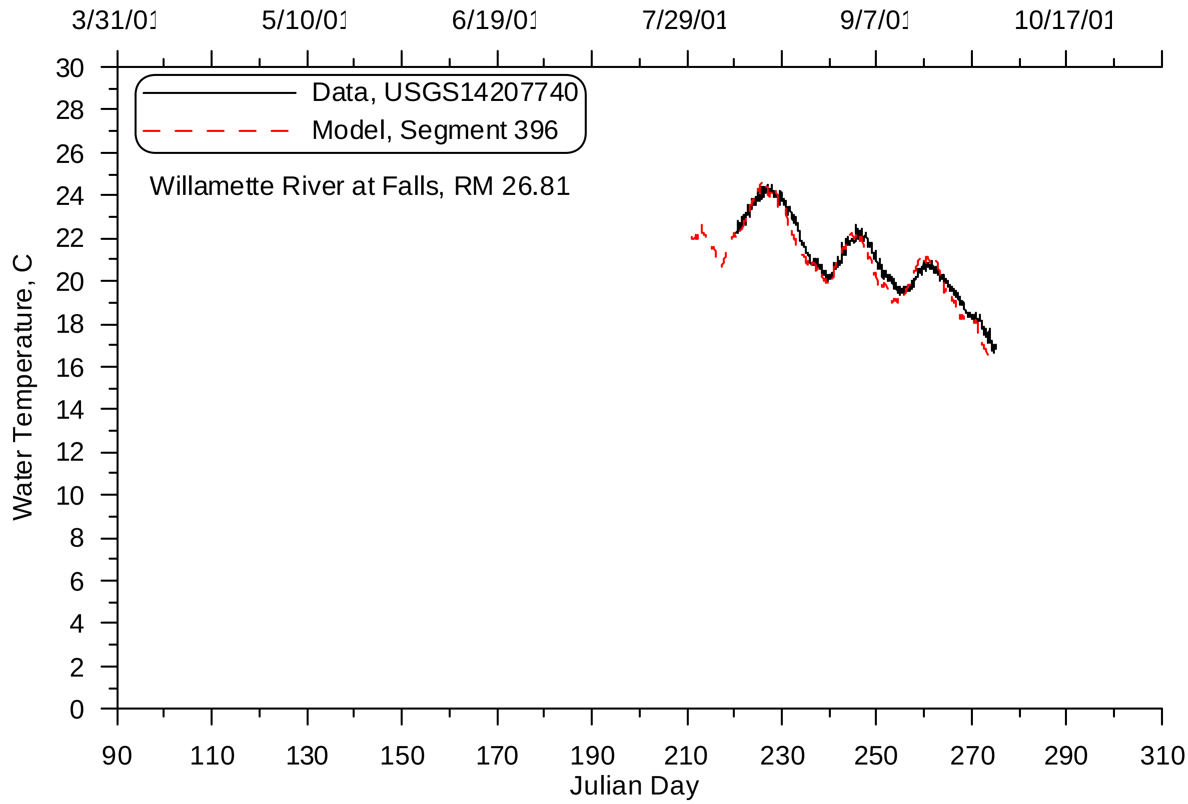

Figure 125: Willamette River at the Willamette Falls model-data continuous temperature comparison, 2001

Year 2002

Model-data error statistics of continuous water temperature for the 2002 Middle Willamette River model are shown in Table 17. Time series plots of continuous temperature predictions and data are shown in Figure 126 through Figure 133. Similar to the result sin 2001 the figures show the model is doing well simulating diurnal temperature swings and weather patterns over 14 days. There is slightly less agreement just above the Willamette Falls in September. Model coefficients were the same as used for year 2001, except for the weir parameters representing the Willamette Falls. Light extinction had a value of 0.45 m^{-1}. Model-data error statistics were all at or below 0.85 ^{o}C.

Table 17: Middle Willamette River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14192015	82.60	18	8784	-0.37	0.45	0.55
LASAR 28255	79.18	40	3202	-0.01	0.37	0.49
LASAR 10344	72.63	82	3207	-0.03	0.38	0.48
DEQ Coffee Island	61.51	156	3110	0.14	0.67	0.85
LASAR 30525	55.30	197	3109	-0.42	0.53	0.66
USGS 14197900	50.11	246	8784	-0.09	0.48	0.60
LASAR 10340	38.94	318	5393	-0.39	0.57	0.71
USGS 14207740	28.81	396	8782	-0.32	0.52	0.65

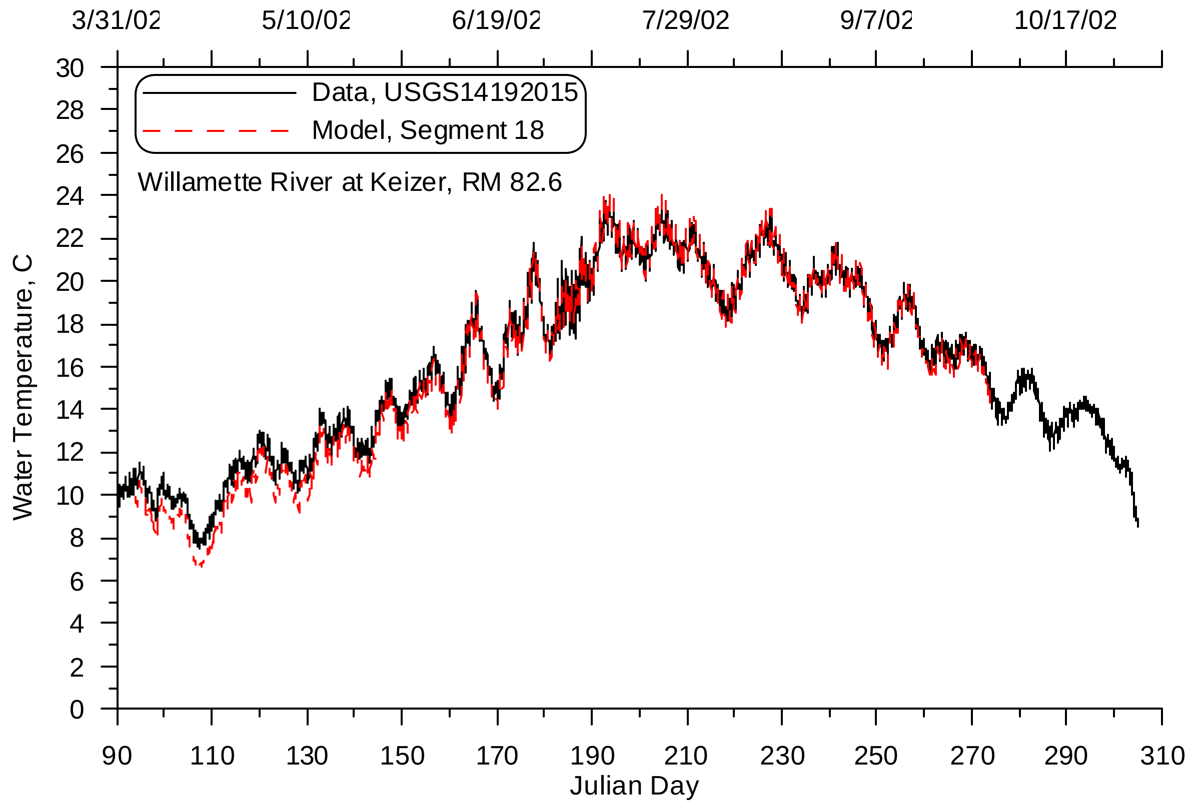

Figure 126: Willamette River at Keizer model-data continuous temperature comparison, 2002

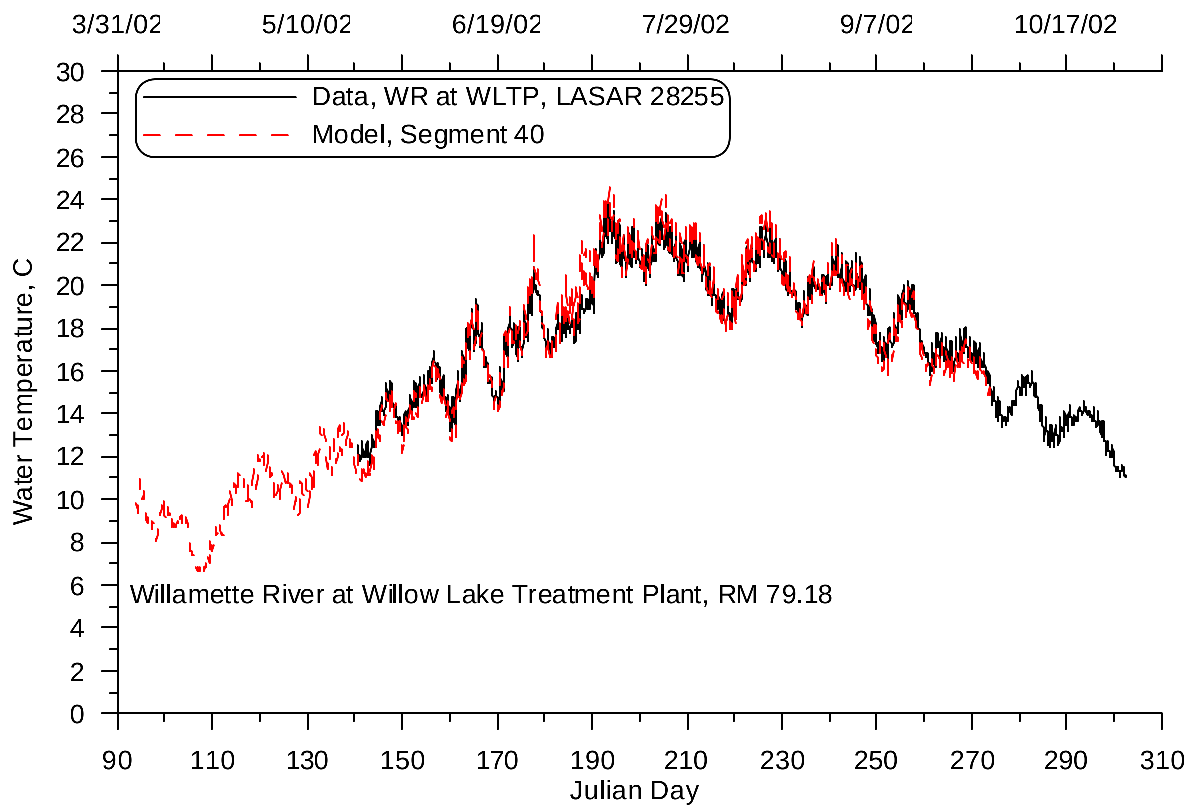

Figure 127: Willamette River at Willow Lake Treatment Plant model-data continuous temperature comparison, 2002

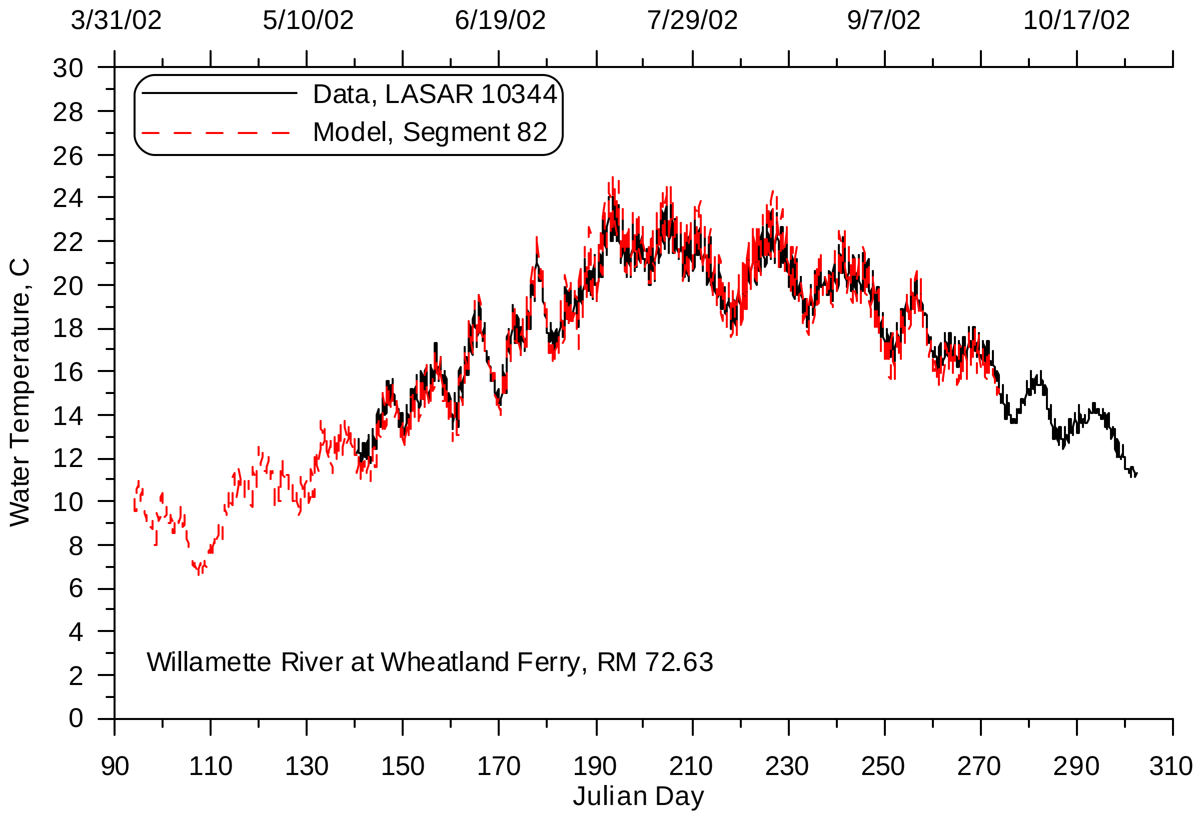

Figure 128: Willamette River at Wheatland Ferry model-data continuous temperature comparison, 2002

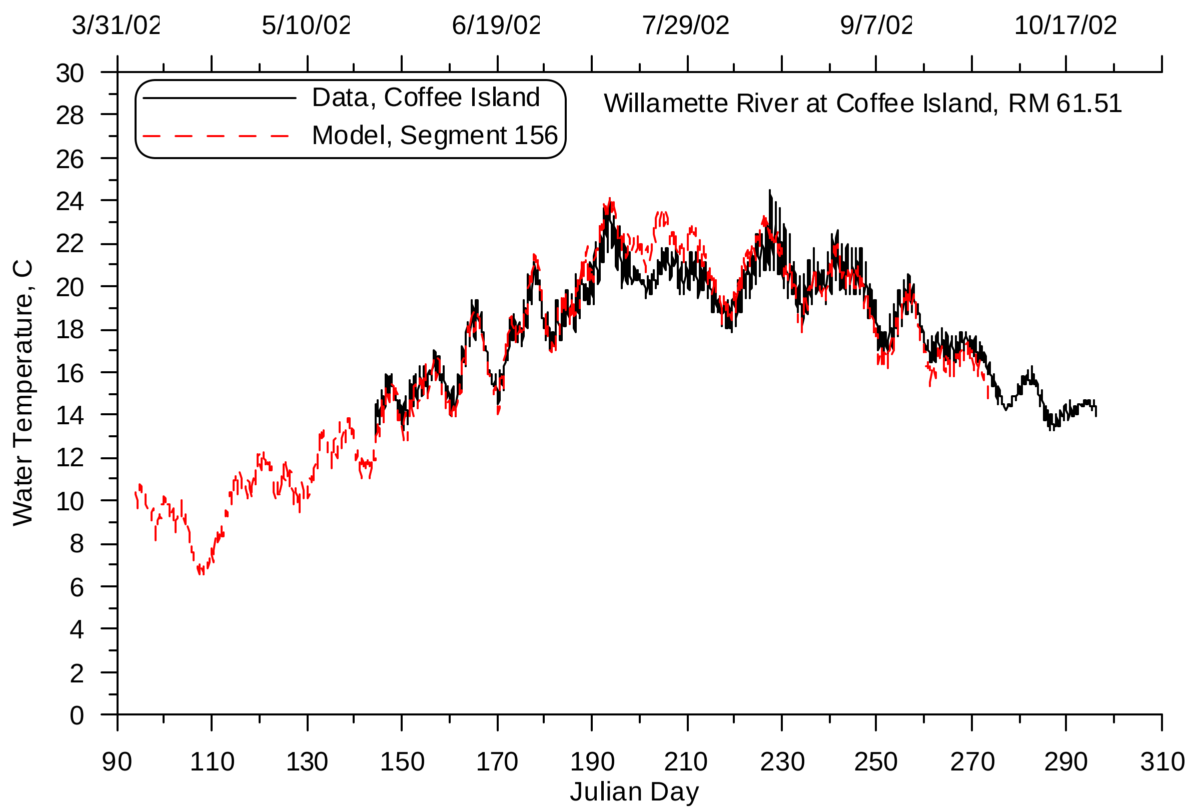

Figure 129: Willamette River at Coffee Island model-data continuous temperature comparison, 2002

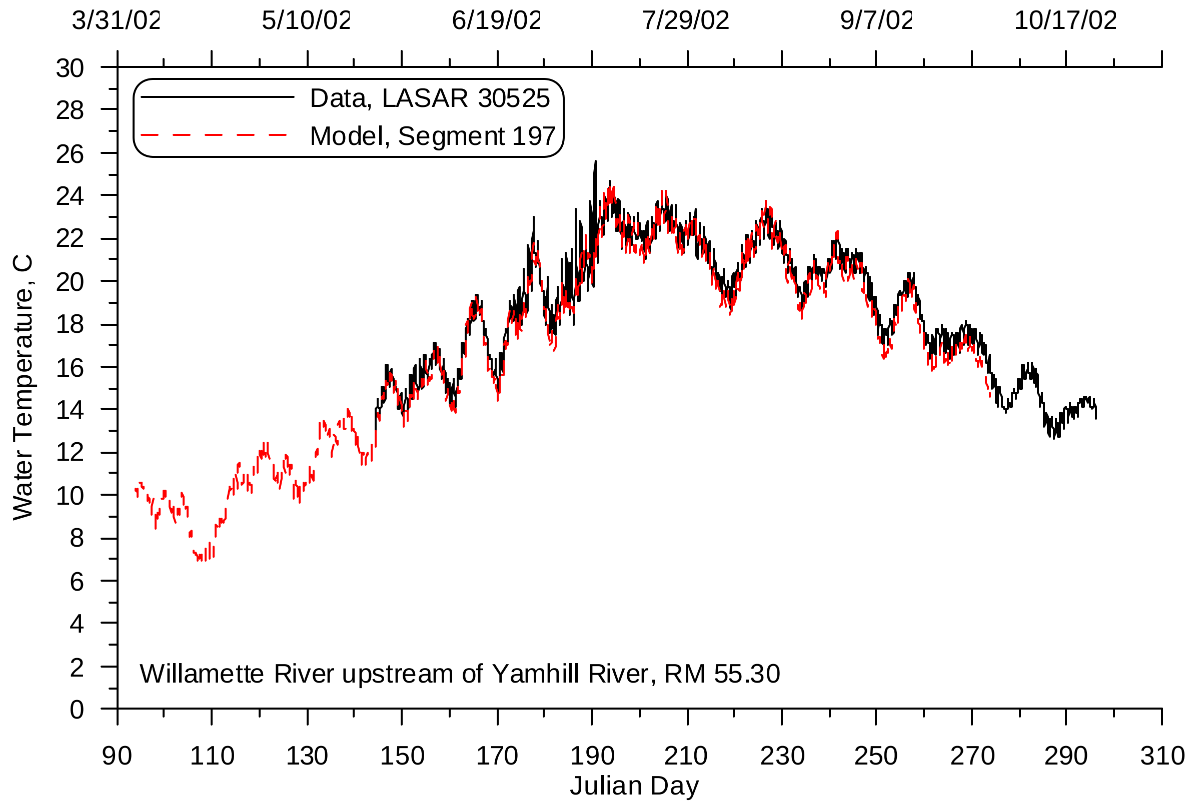

Figure 130: Willamette River upstream of the Yamhill River model-data continuous temperature comparison, 2002

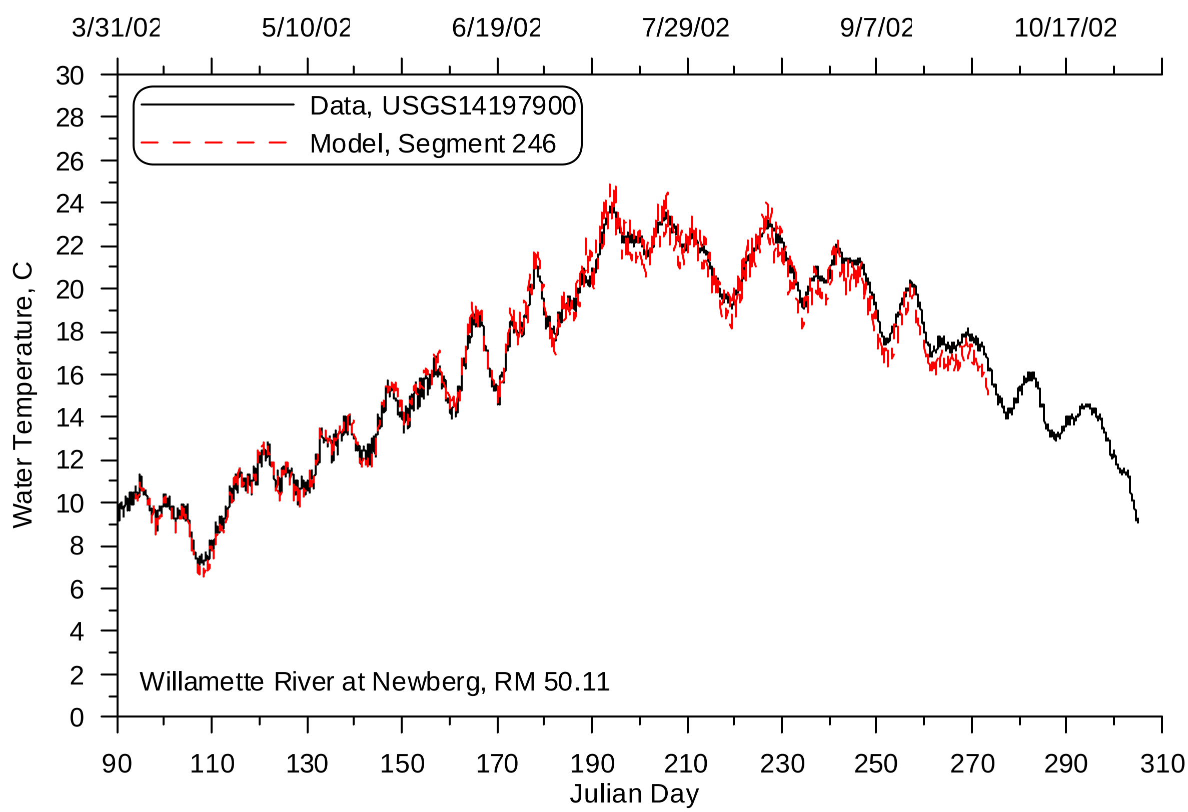

Figure 131: Willamette River at Newberg model-data continuous temperature comparison, 2002

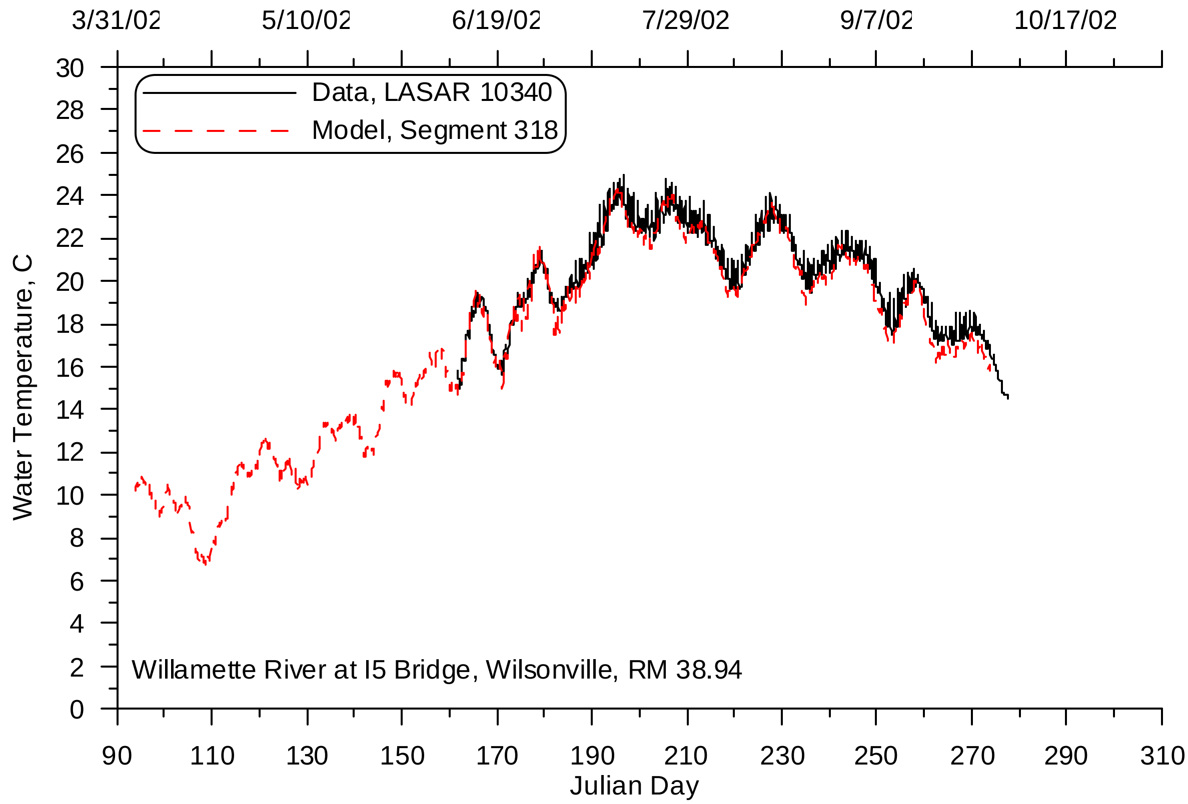

Figure 132: Willamette River at I5 Bridge, Wilsonville model-data continuous temperature comparison, 2002

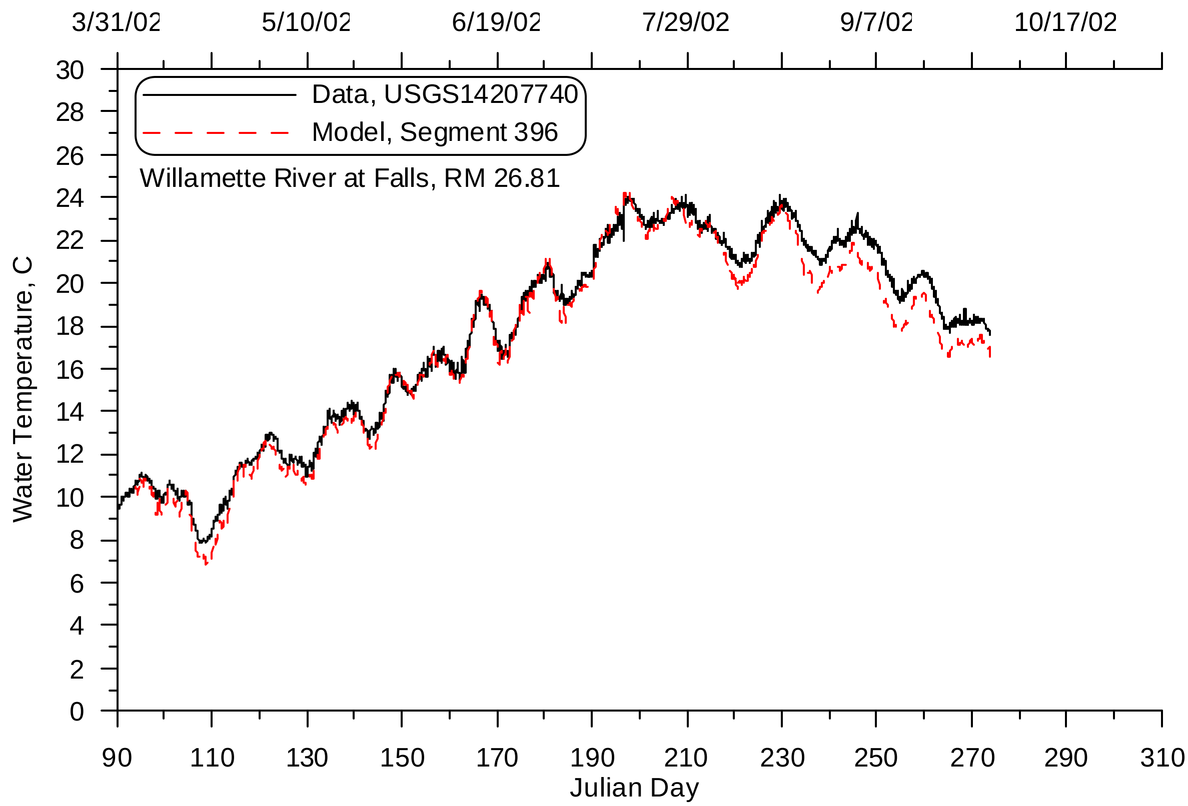

Figure 133: Willamette River at the Willamette Falls model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

Year 2001

Table 18 lists model-data error statistics for daily maximum water temperature for the 2001 Middle Willamette River model. Figure 134 through Figure 163 show plots of model predicted daily maximum temperature and data. Similar to the continuous temperature results for 2001 the daily maximum temperatures from the model agree well with the data for the sites in the Middle Willamette River. Model-data error statistics were all at or below 0.85 ^{o}C with the exception of one data set at one location.

Table 18: Middle Willamette River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14191000	85.66	5	11	-0.07	0.13	0.25
USGS 14192015	82.60	18	60	0.13	0.35	0.40
LASAR 28255	79.18	40	60	0.49	0.49	0.55
LASAR 10344	72.63	82	66	0.66	0.70	0.79
PGE Eagle Nest A	63.95	140	66	0.14	0.29	0.37
PGE Eagle Nest B	63.95	140	66	0.08	0.29	0.36
PGE Coffee Island A	61.51	156	66	-0.81	0.85	0.95
PGE Coffee Island B	61.51	156	66	-0.64	0.70	0.80
PGE San Salvador A	55.58	196	66	0.28	0.51	0.61
PGE San Salvador B	55.58	196	66	0.29	0.51	0.61
PGE Ash Island A	52.76	228	66	0.47	0.62	0.75
PGE Ash Island B	52.76	228	66	0.31	0.54	0.65
PGE Champoeg Dock A	45.21	277	66	0.02	0.41	0.48
PGE Champoeg Dock B	45.21	277	66	0.10	0.42	0.49
LASAR 10340	38.94	318	66	-0.56	0.59	0.70
PGE US Molalla R. A	36.17	336	66	-0.70	0.73	0.85
PGE US Molalla R. B	36.17	336	66	-0.31	0.50	0.62
PGE Canby A	34.32	348	66	-0.14	0.35	0.44
PGE Canby B	34.32	348	66	0.05	0.33	0.41
PGE Powerline A	29.37	380	66	0.00	0.42	0.49
PGE Powerline B	29.37	380	66	0.12	0.43	0.52
PGE Tug Dock A	28.61	384	66	0.10	0.35	0.41
PGE Tug Dock B	28.61	384	66	-0.18	0.37	0.43
PGE Boathouse A	27.27	393	66	-0.33	0.44	0.55
PGE Boathouse B	27.27	393	66	-0.30	0.44	0.54
PGE Forebay A	26.81	396	66	0.15	0.49	0.58
PGE Forebay B	26.81	396	66	0.31	0.52	0.64
PGE Log Boom A	26.81	396	66	0.14	0.50	0.59
PGE Log Boom B	26.81	396	52	0.27	0.51	0.62
USGS 14207740	28.81	396	54	0.08	0.41	0.48

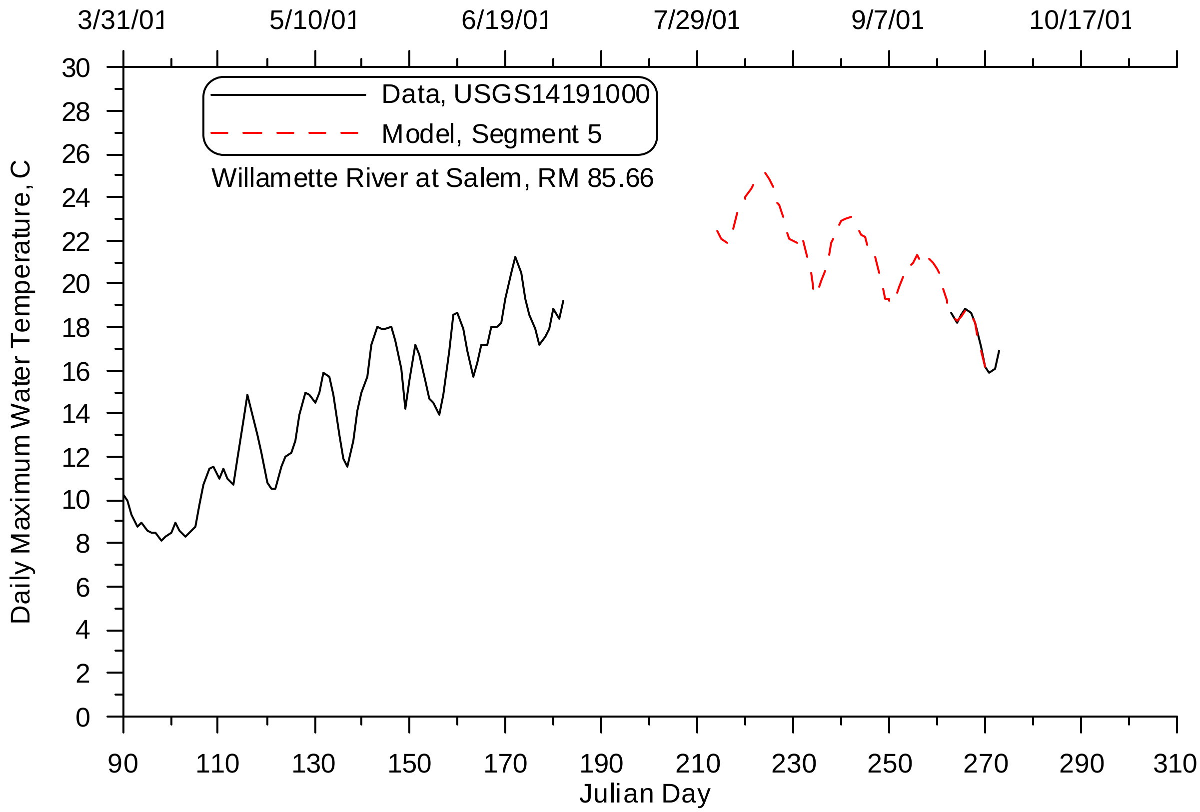

Figure 134: Willamette River at Salem model-data daily maximum temperature comparison, 2001

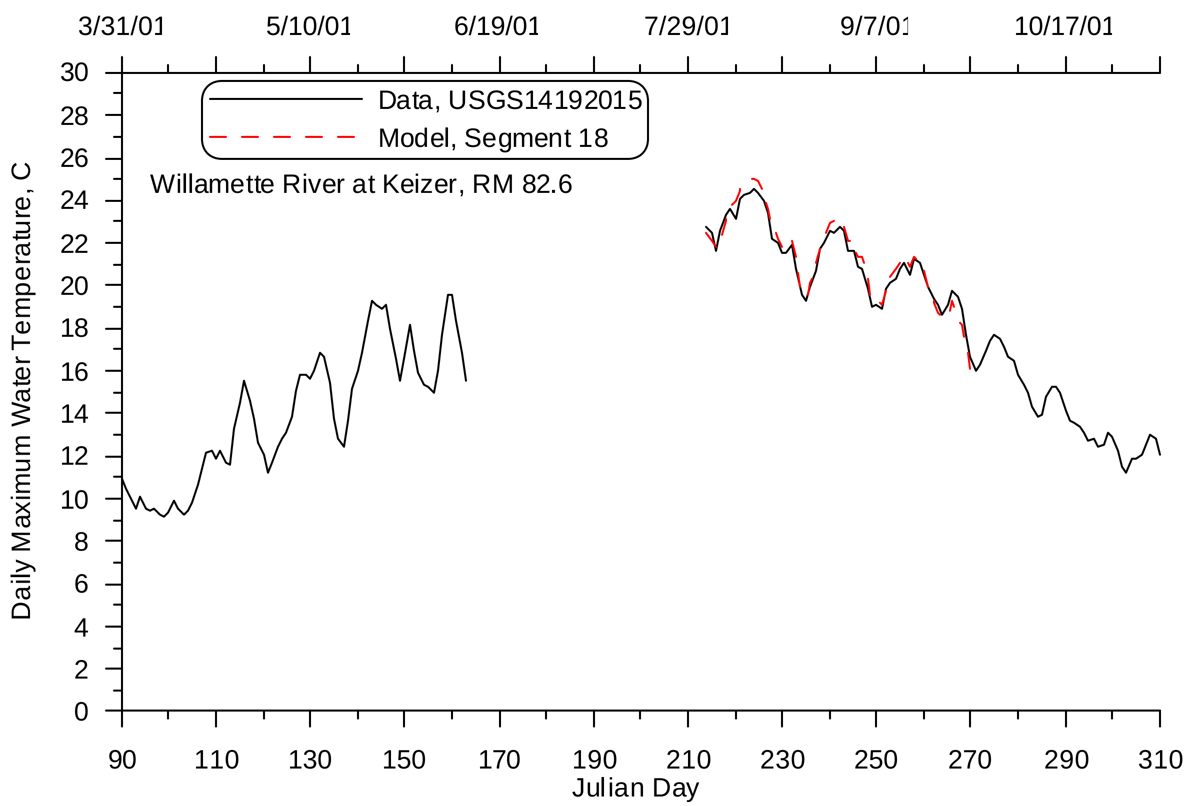

Figure 135: Willamette River at Keizer model-data daily maximum temperature comparison, 2001

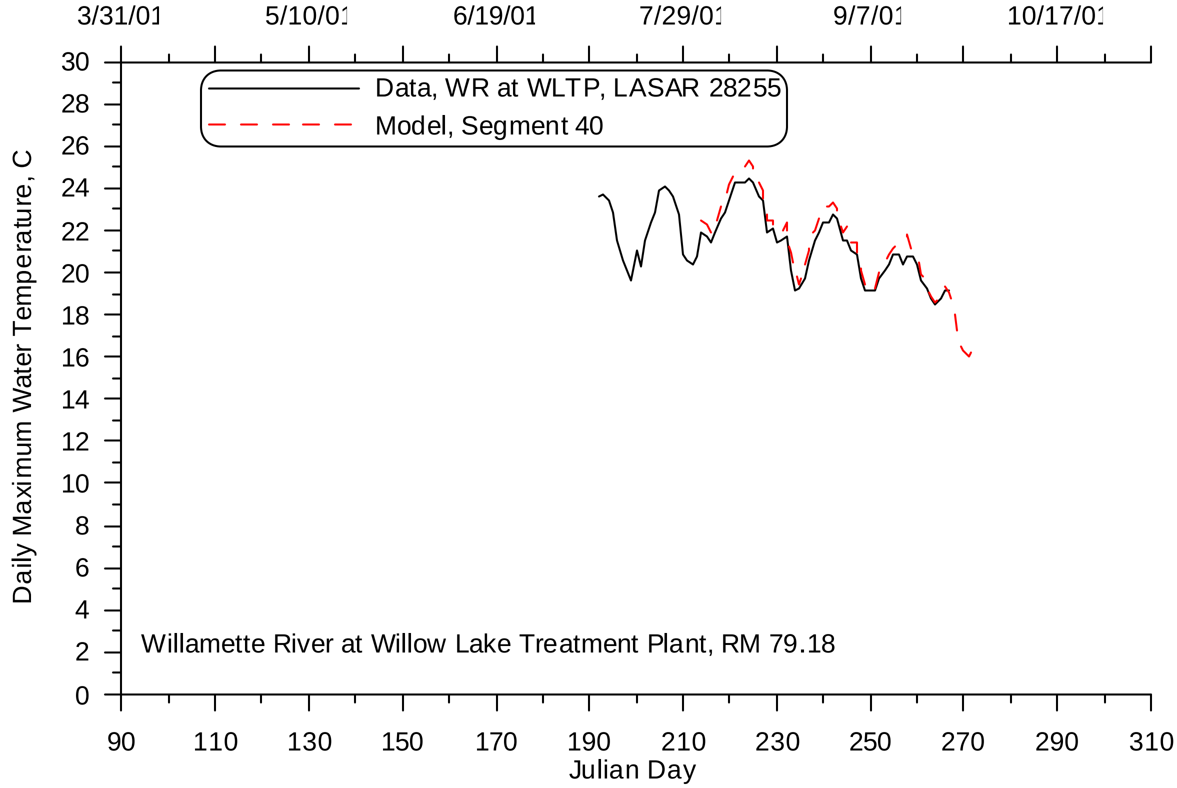

Figure 136: Willamette River at Willow Lake Treatment Plant model-data daily maximum temperature comparison, 2001

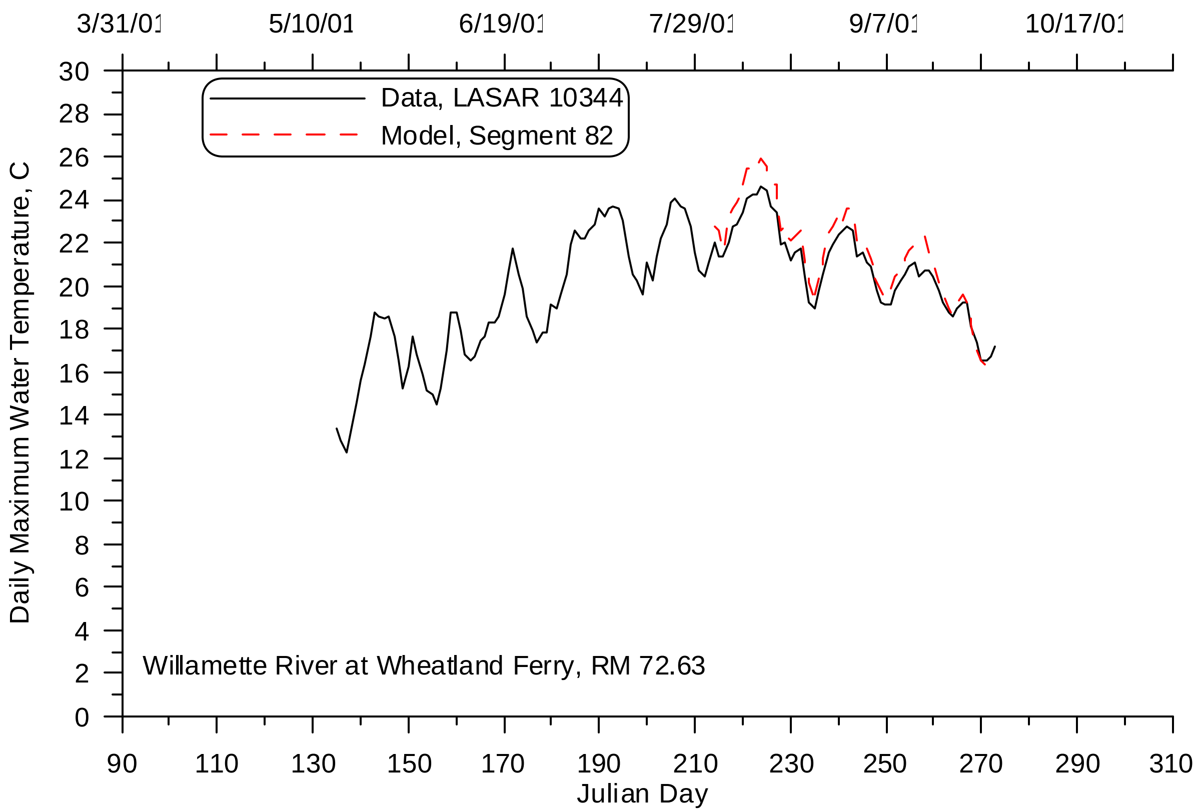

Figure 137: Willamette River at Wheatland Ferry model-data daily maximum temperature comparison, 2001

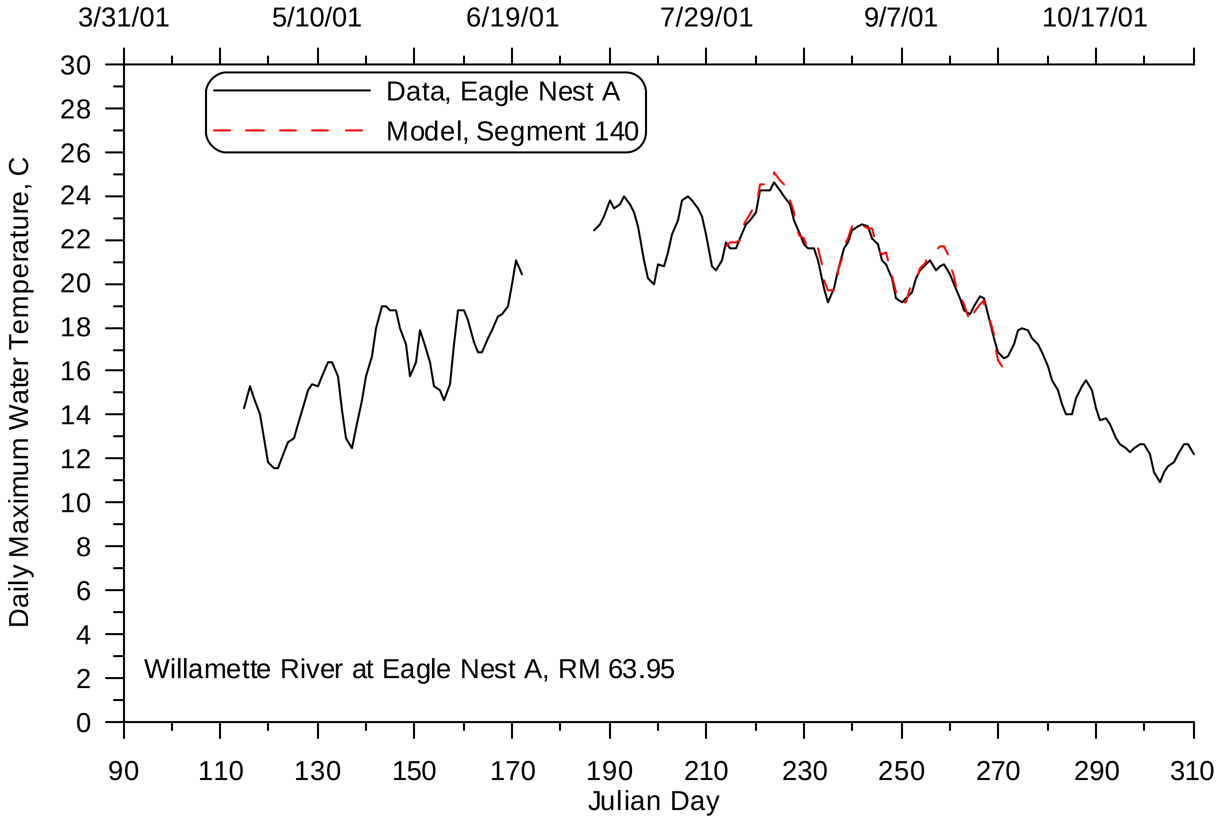

Figure 138: Willamette River at Eagle Nest A model-data daily maximum temperature comparison, 2001

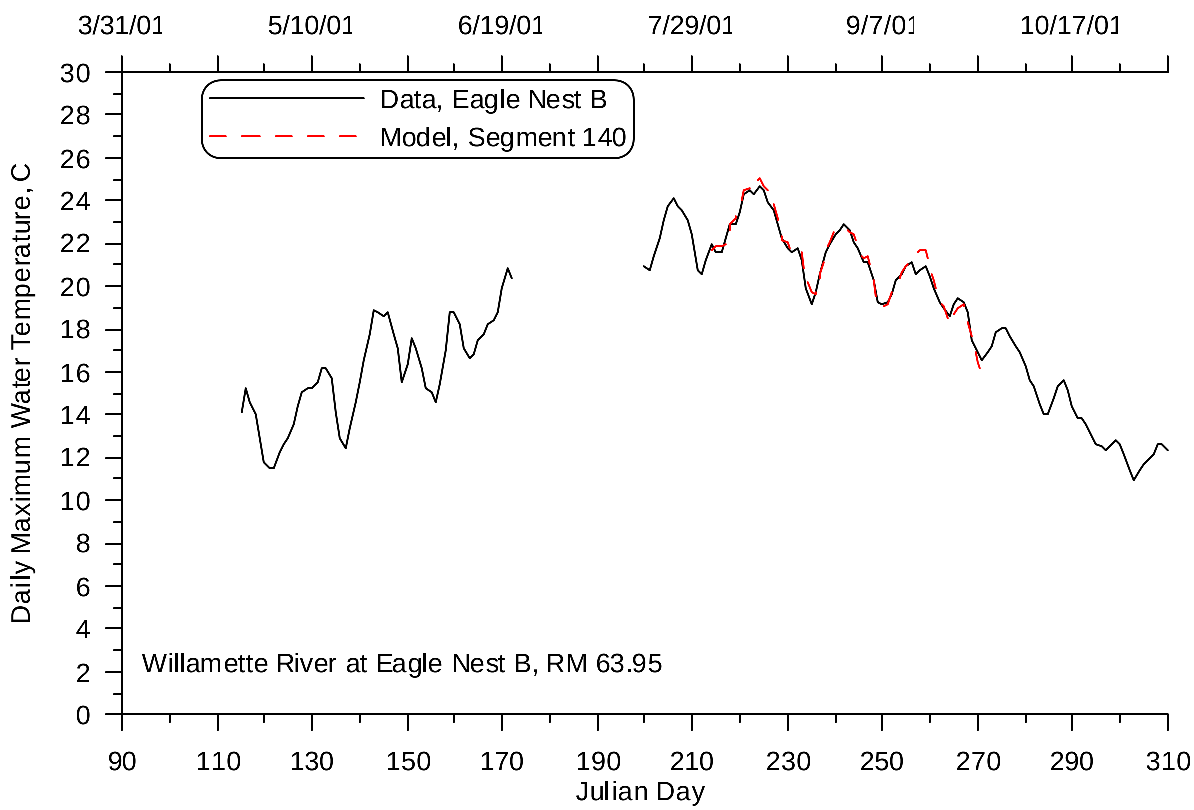

Figure 139: Willamette River at Eagle Nest B model-data daily maximum temperature comparison, 2001

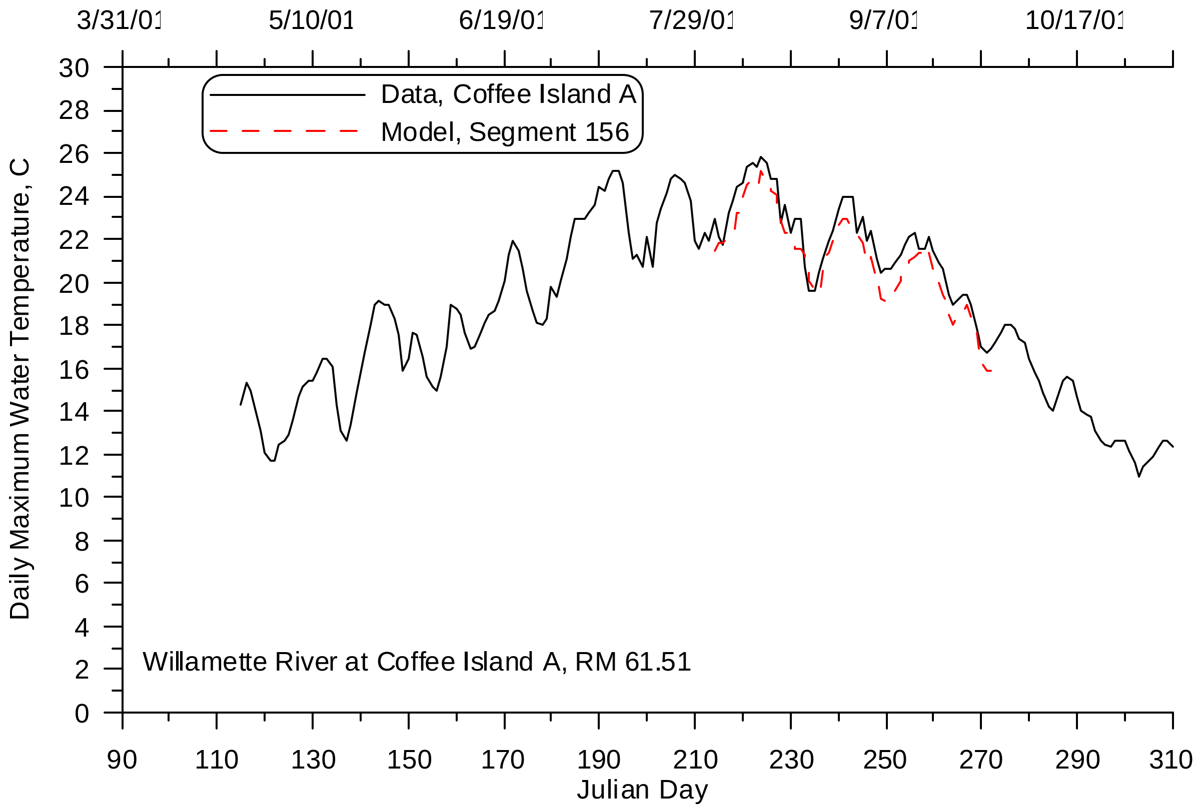

Figure 140: Willamette River at Coffee Island A model-data daily maximum temperature comparison, 2001

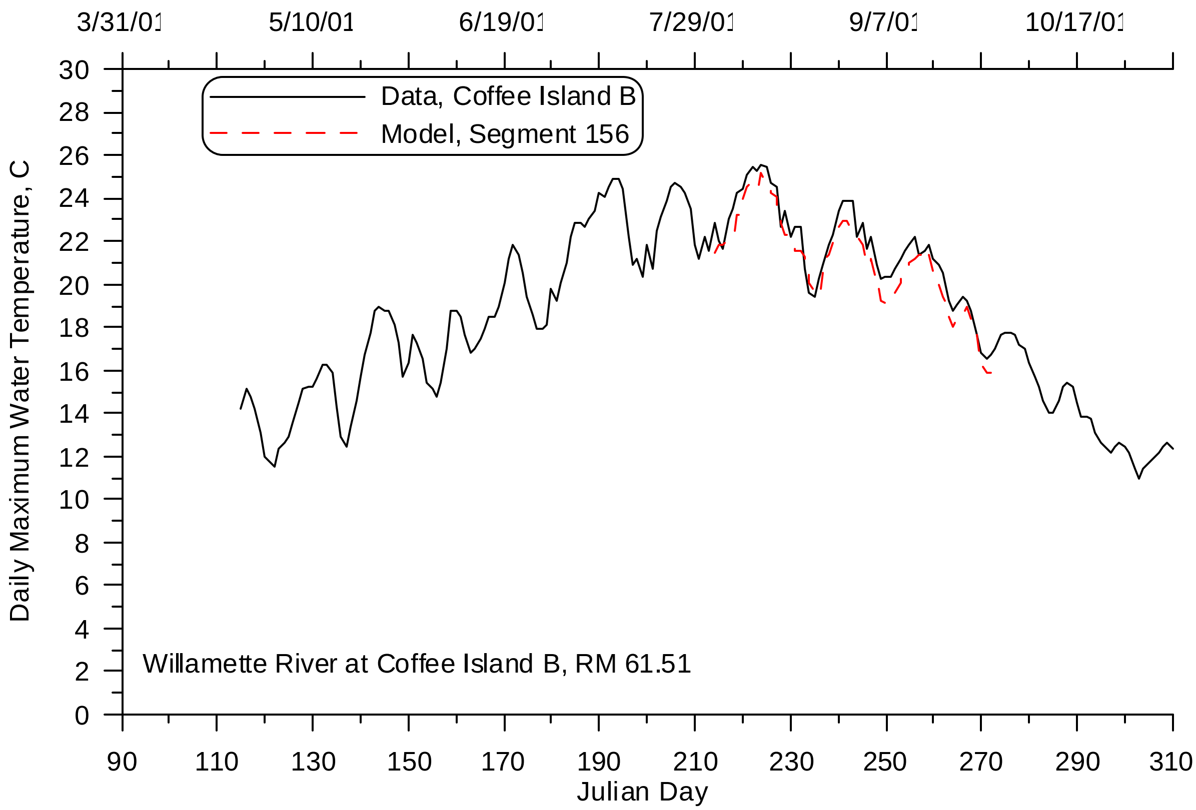

Figure 141: Willamette River at Coffee Island B model-data daily maximum temperature comparison, 2001

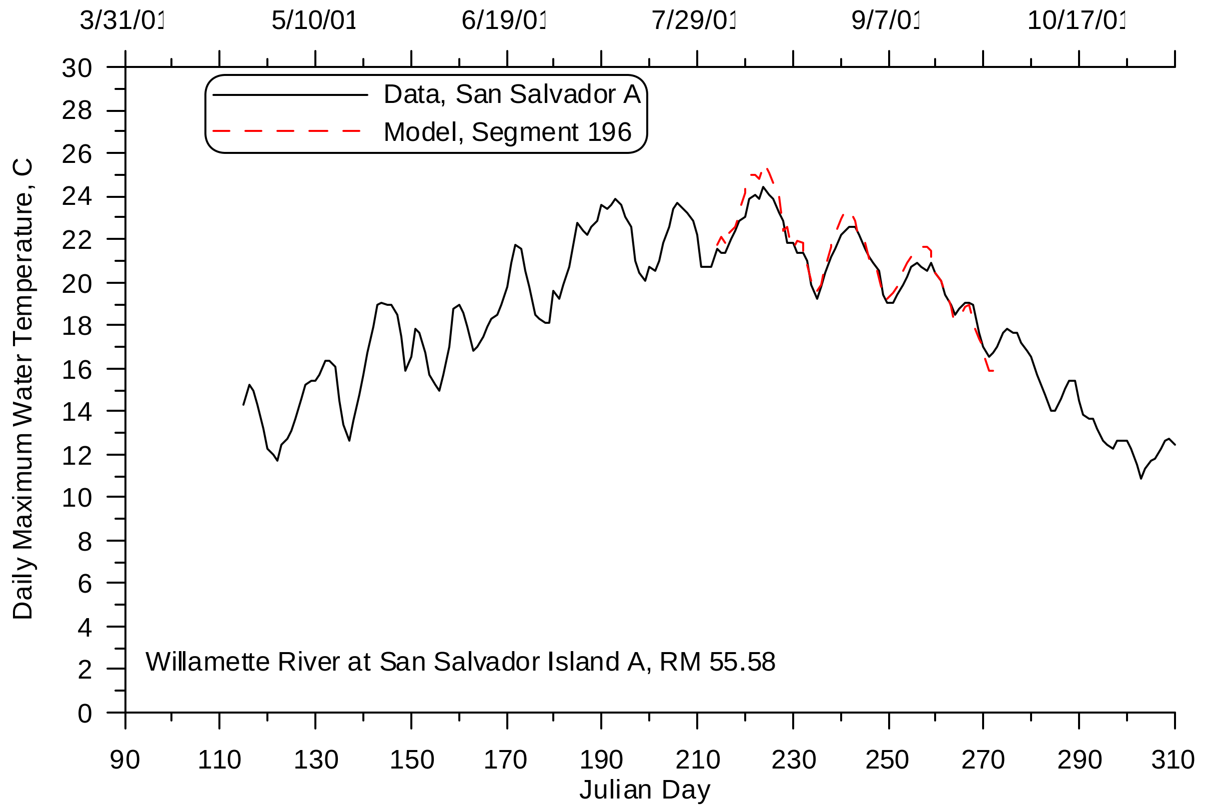

Figure 142: Willamette River at San Salvador A model-data daily maximum temperature comparison, 2001

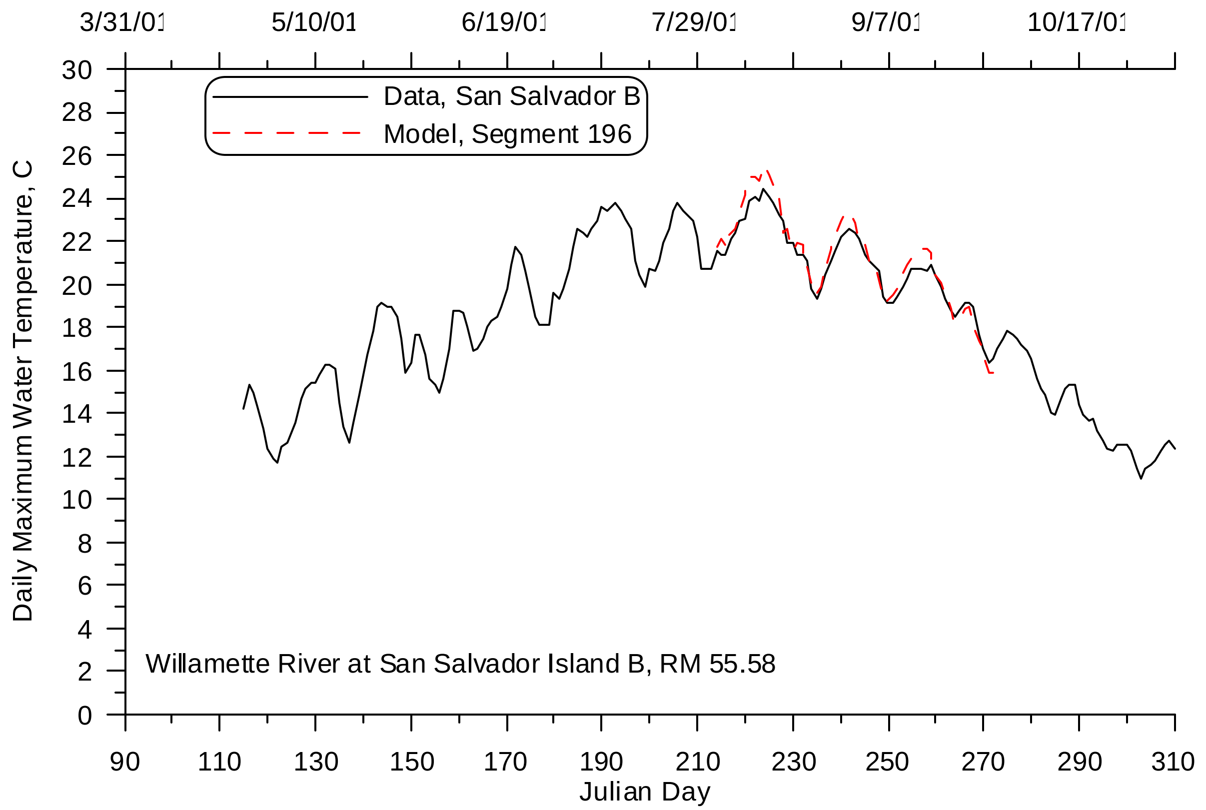

Figure 143: Willamette River at San Salvador B model-data daily maximum temperature comparison, 2001

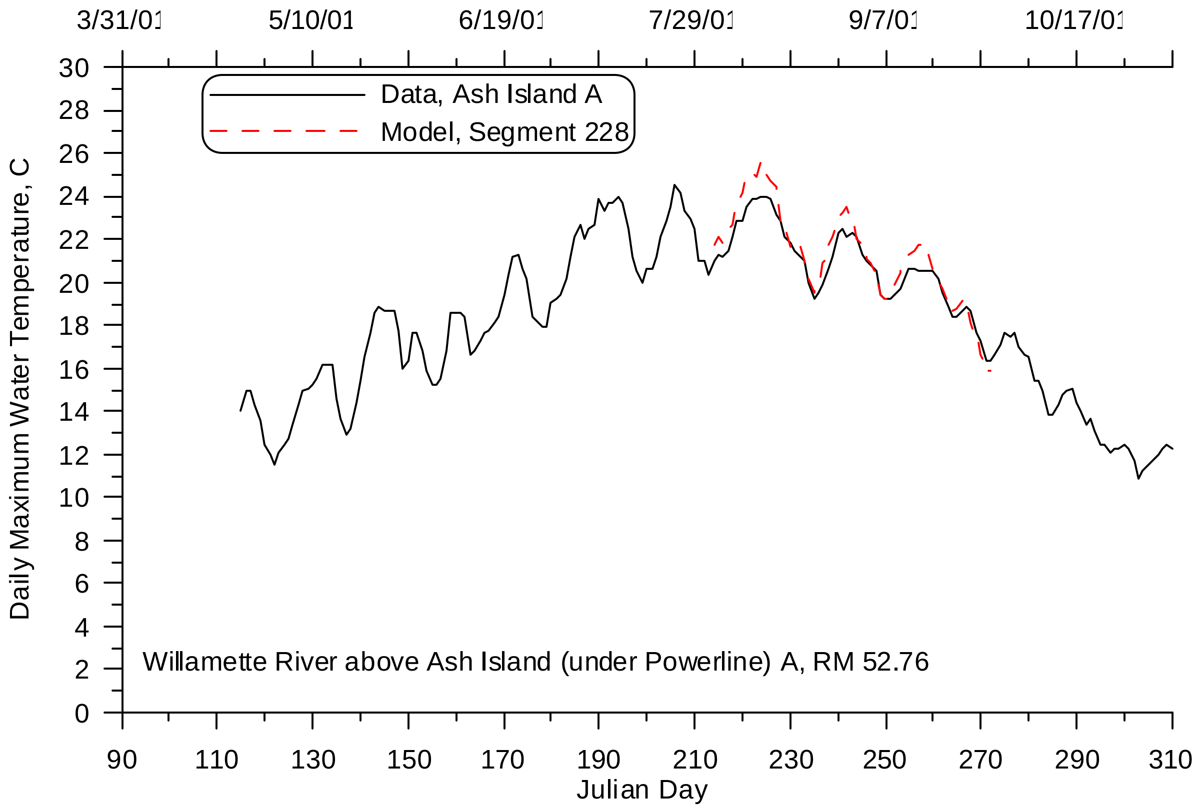

Figure 144: Willamette River above Ash Island A model-data daily maximum temperature comparison, 2001

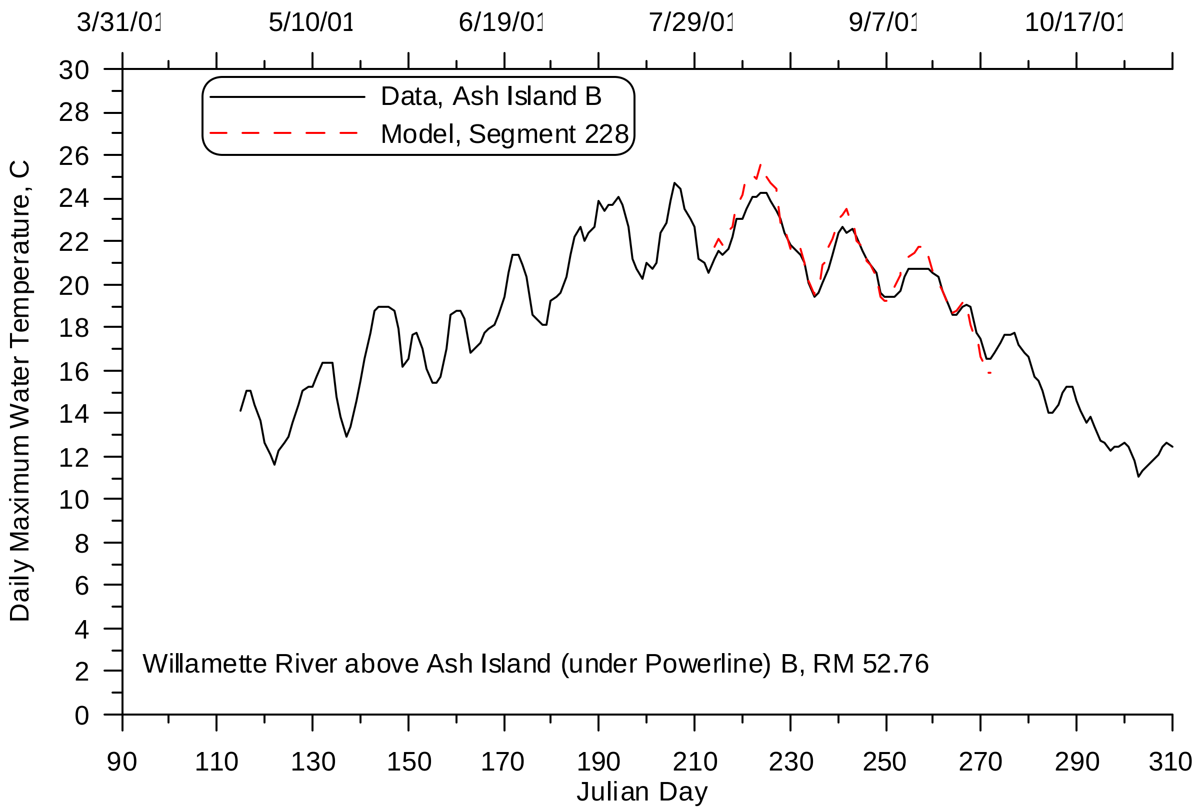

Figure 145: Willamette River above Ash Island B model-data daily maximum temperature comparison, 2001

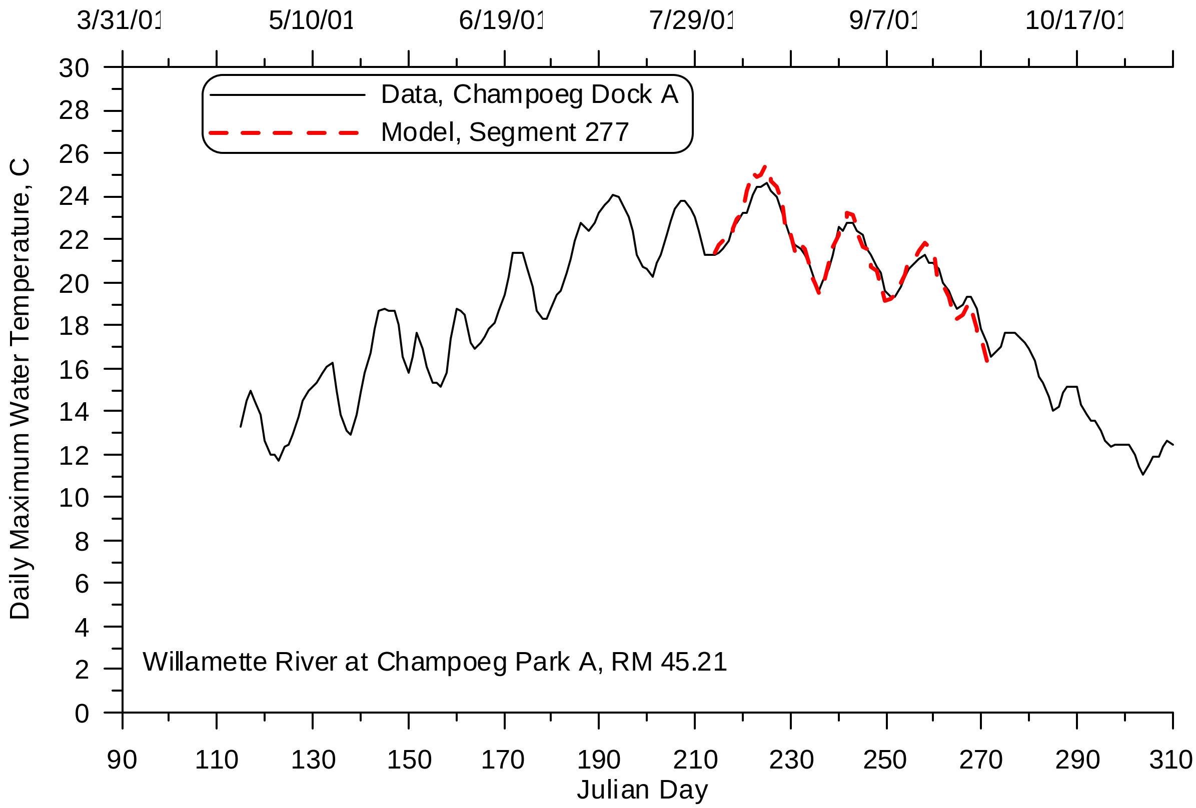

Figure 146: Willamette River at Champoeg Park A model-data daily maximum temperature comparison, 2001

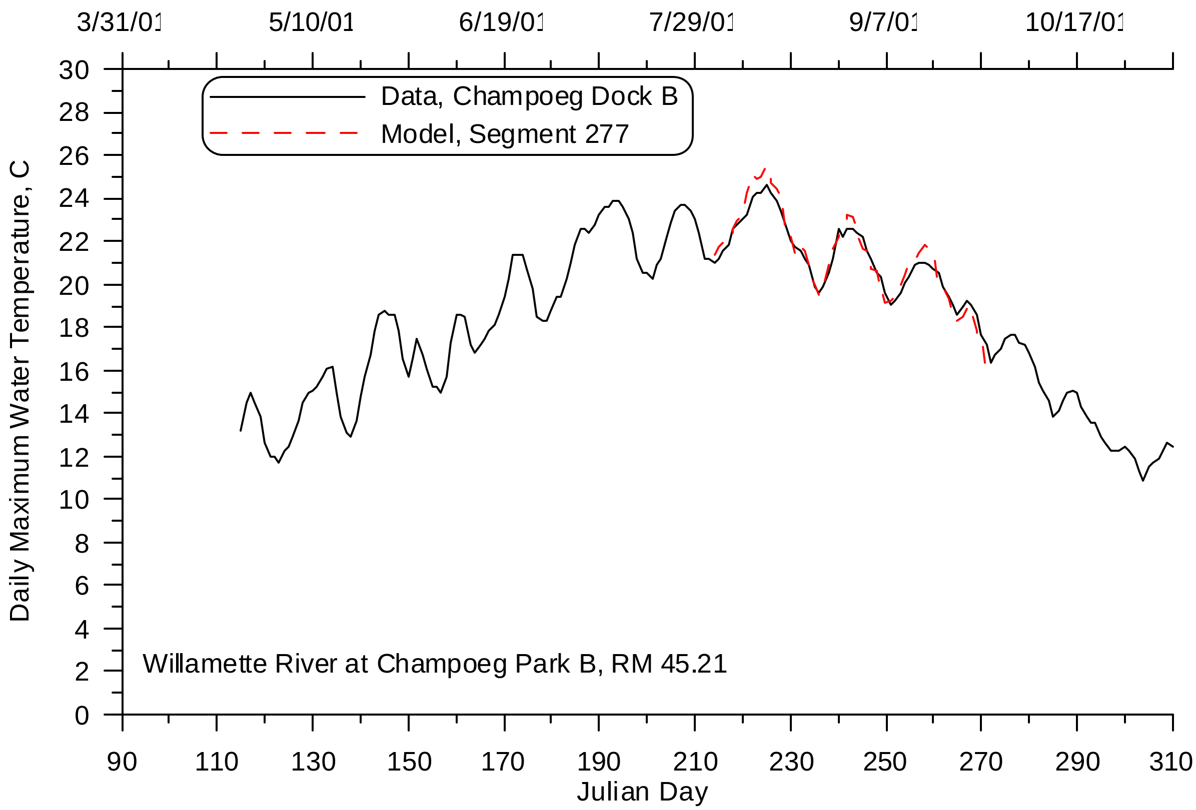

Figure 147: Willamette River at Champoeg Park B model-data daily maximum temperature comparison, 2001

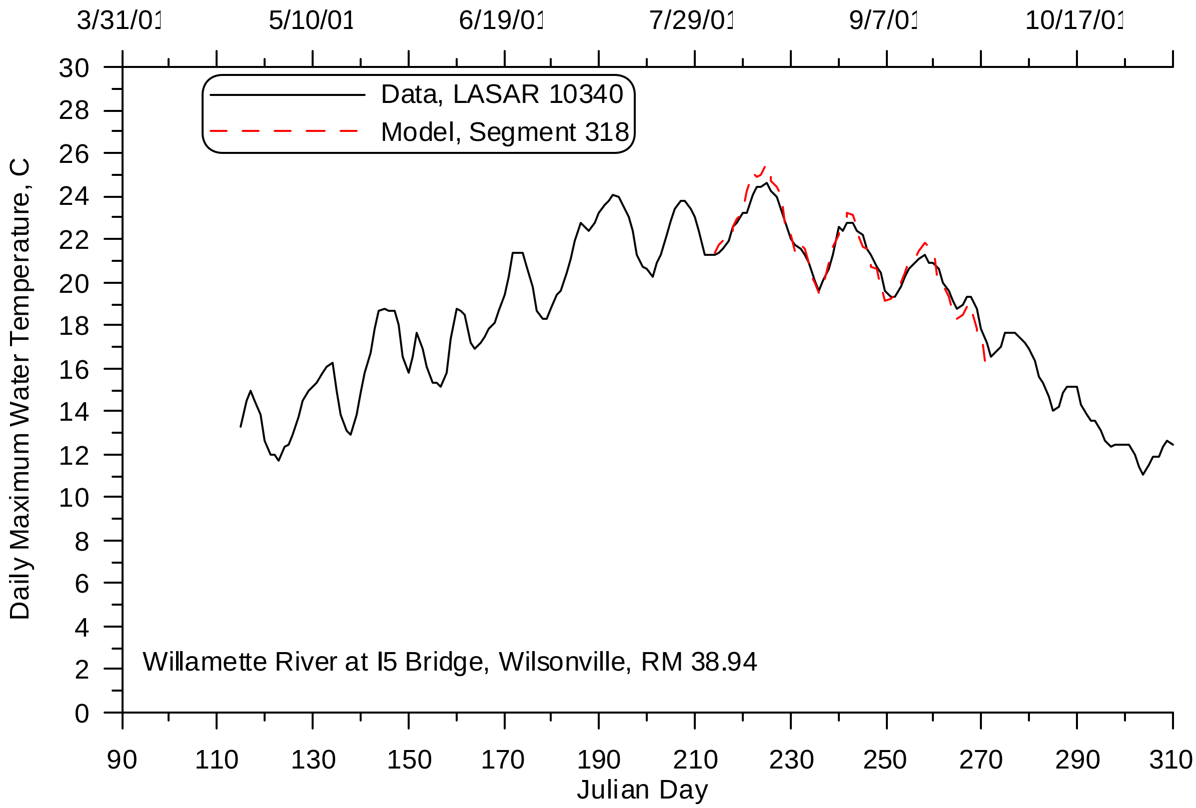

Figure 148: Willamette River at I5 Bridge, Wilsonville model-data daily maximum temperature comparison, 2001

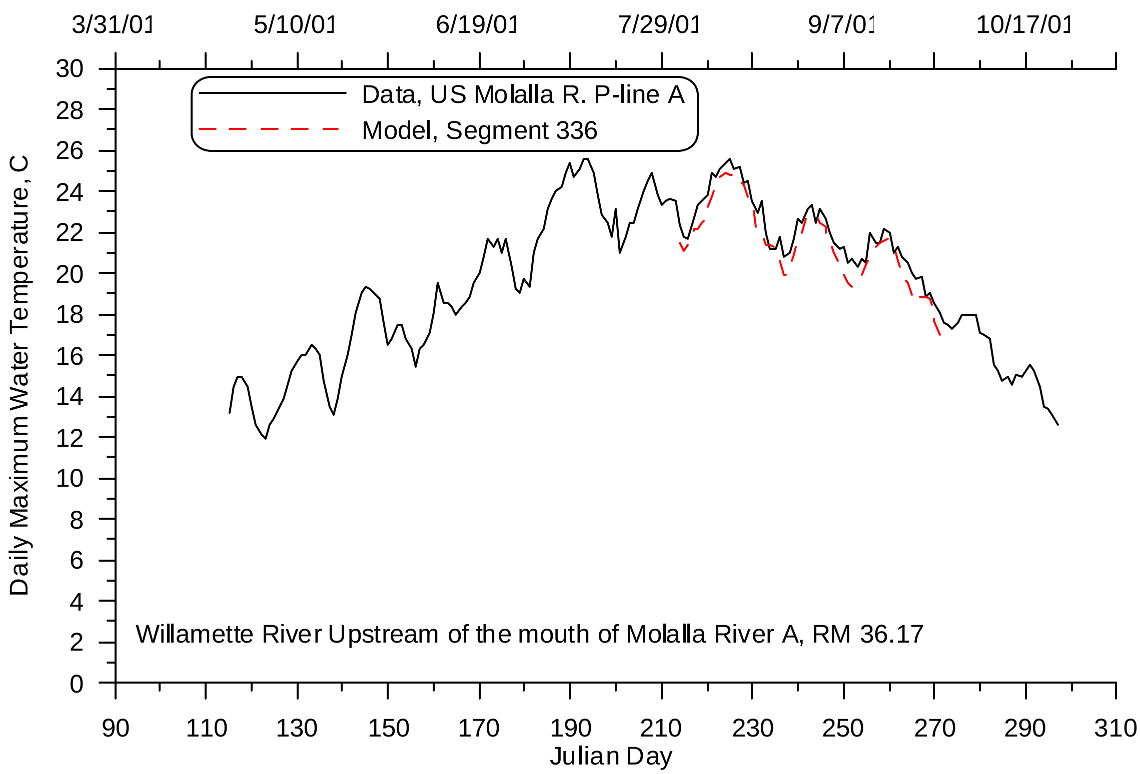

Figure 149: Willamette River upstream of the Molalla River confluence, Power-line A model-data daily maximum temperature comparison, 2001.

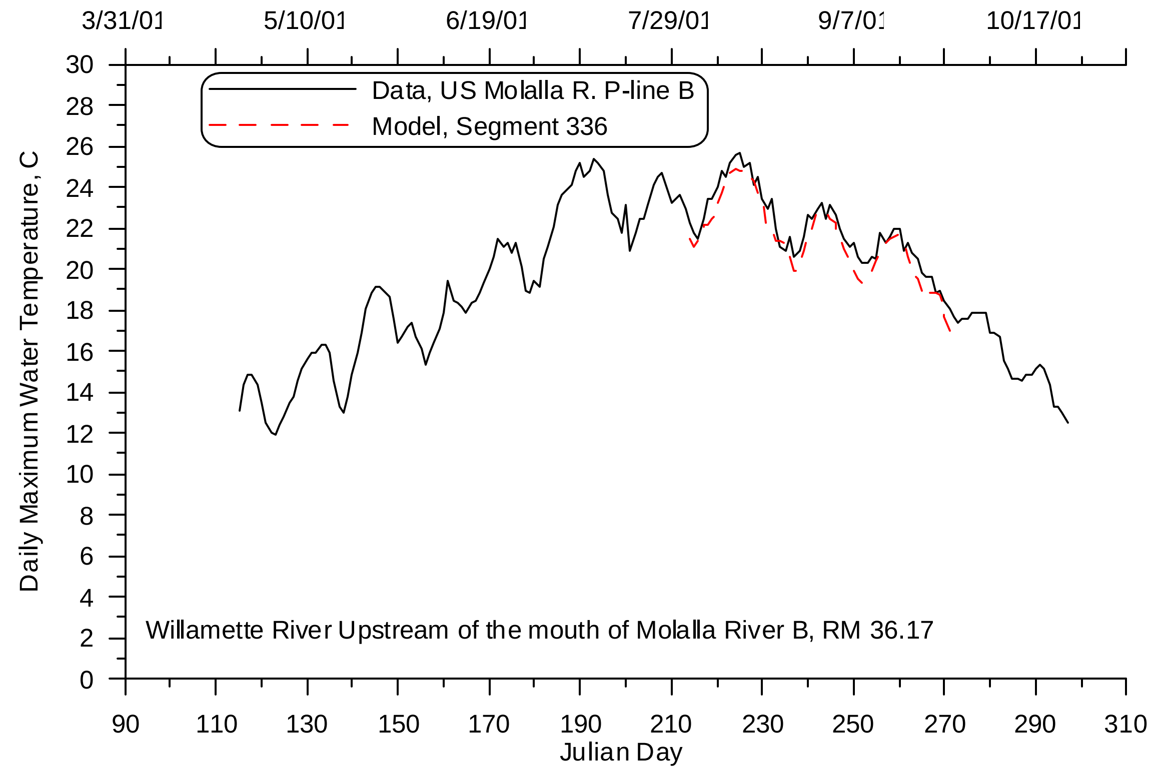

Figure 150: Willamette River upstream of the Molalla River confluence, Power-line B model-data daily maximum temperature comparison, 2001.

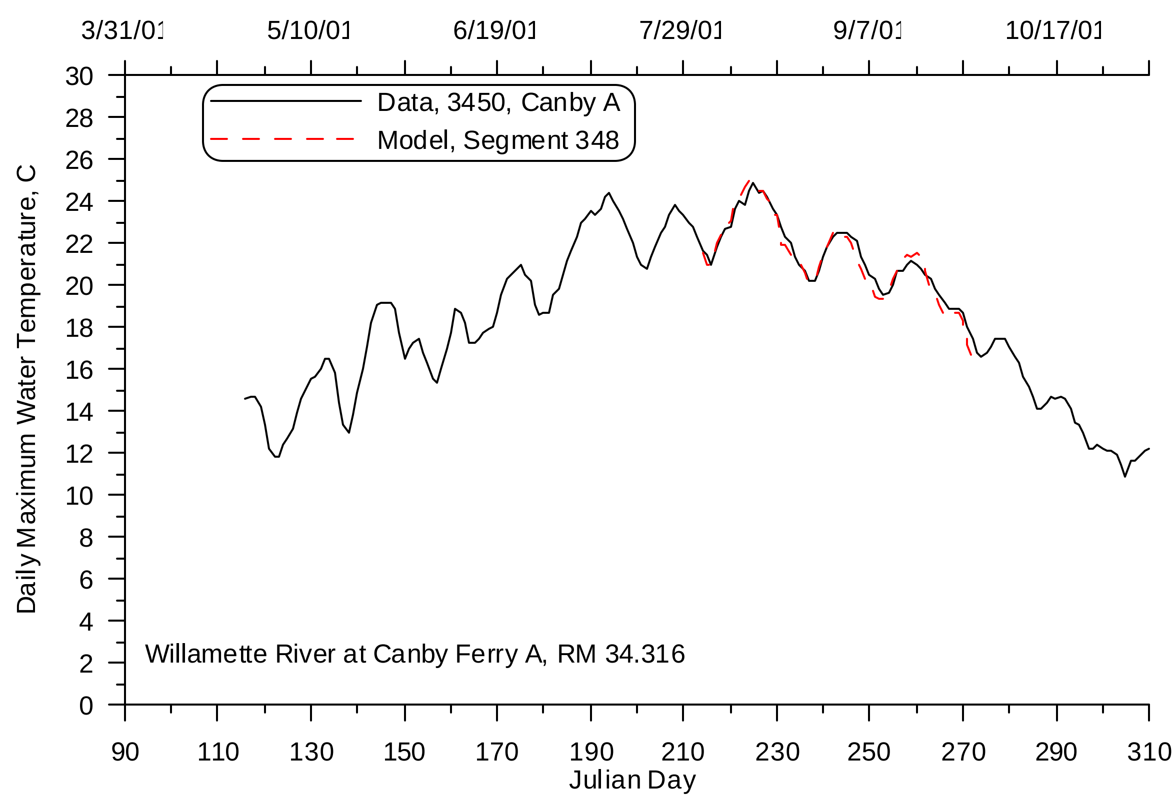

Figure 151: Willamette River at Canby Ferry A model-data daily maximum temperature comparison, 2001.

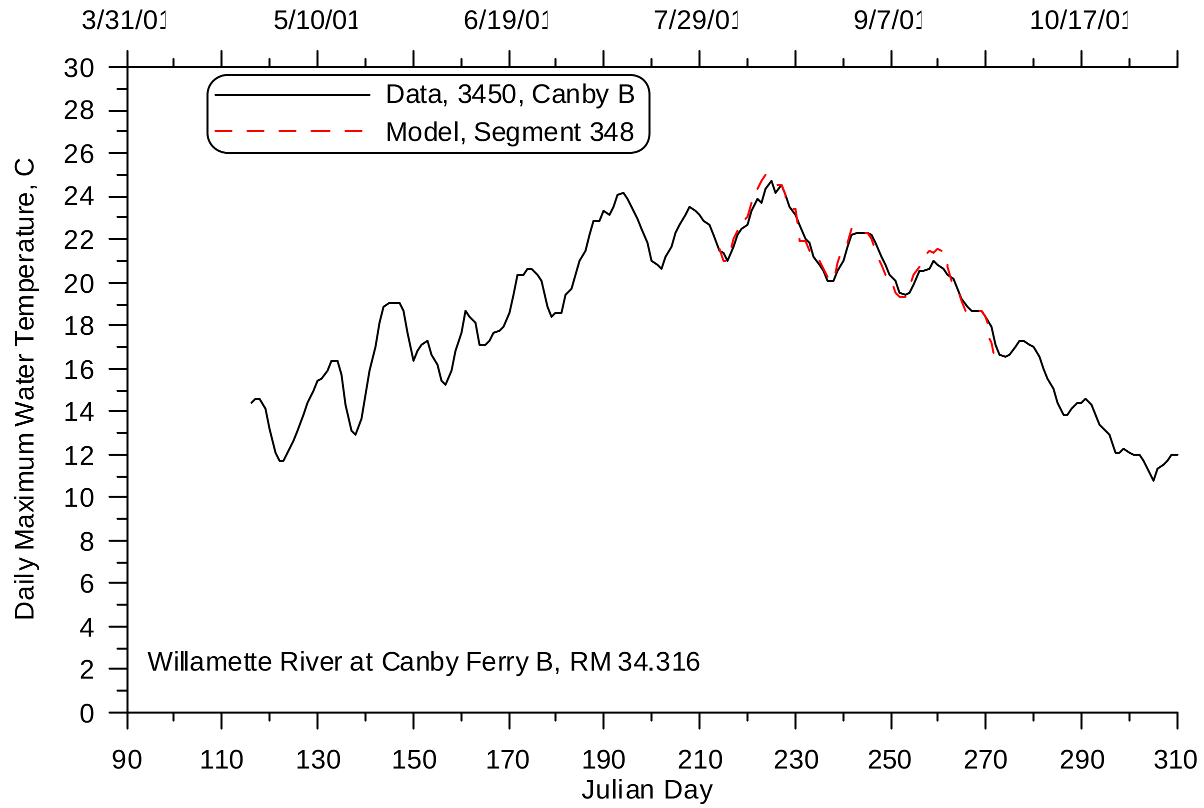

Figure 152: Willamette River at Canby Ferry B model-data daily maximum temperature comparison, 2001.

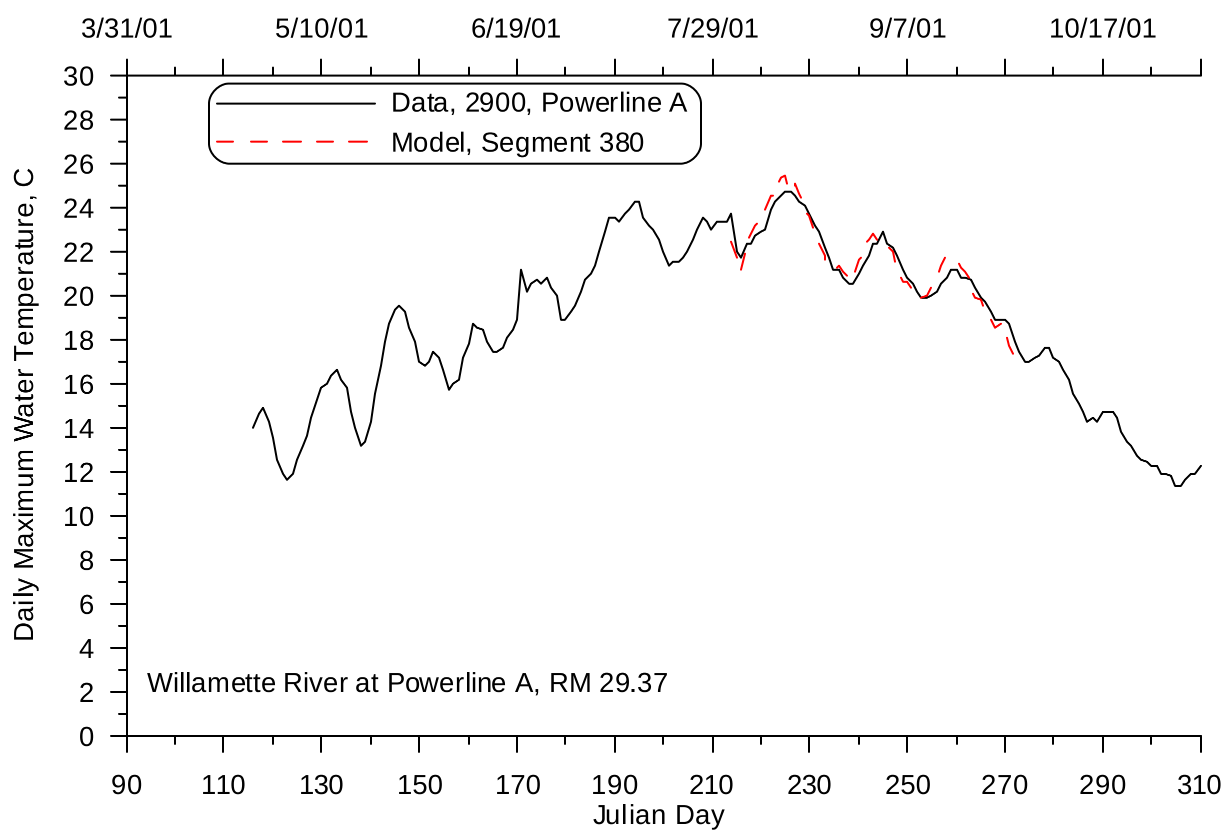

Figure 153: Willamette River at Powerline A model-data daily maximum temperature comparison, 2001

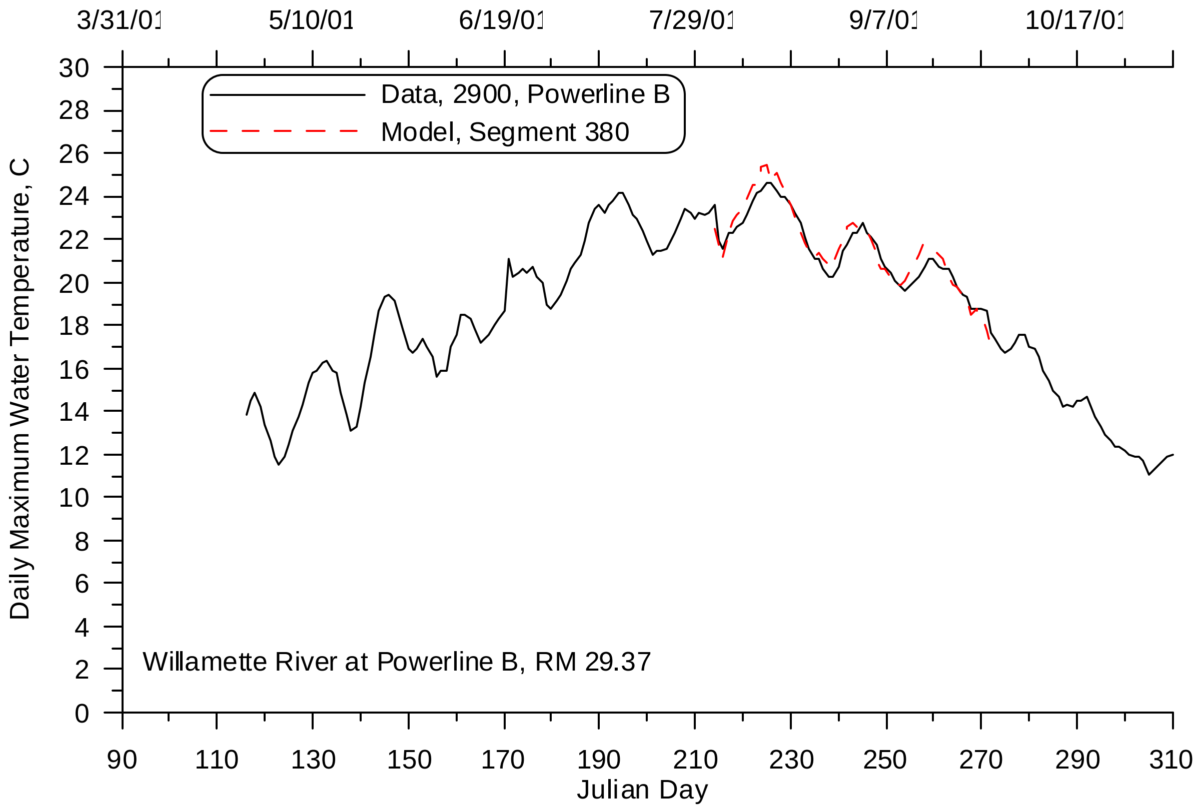

Figure 154: Willamette River at Powerline B model-data daily maximum temperature comparison, 2001

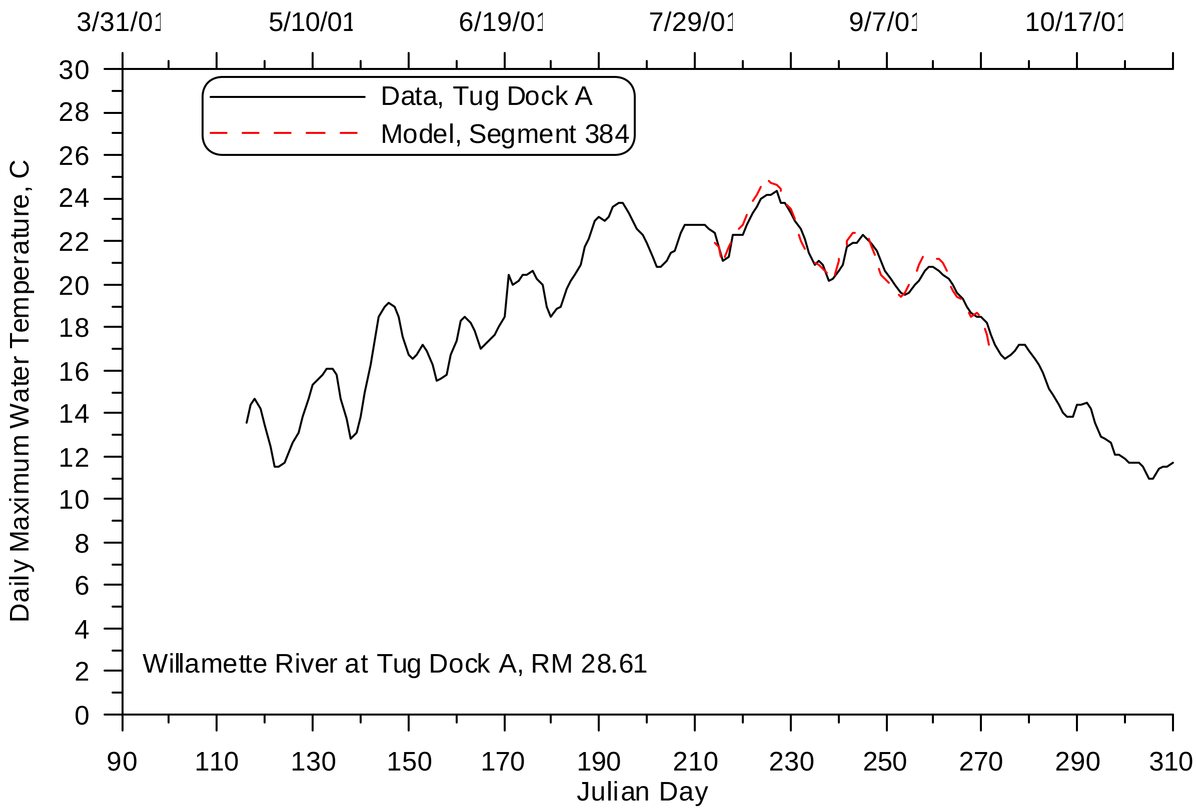

Figure 155: Willamette River at Tug Dock A model-data daily maximum temperature comparison, 2001

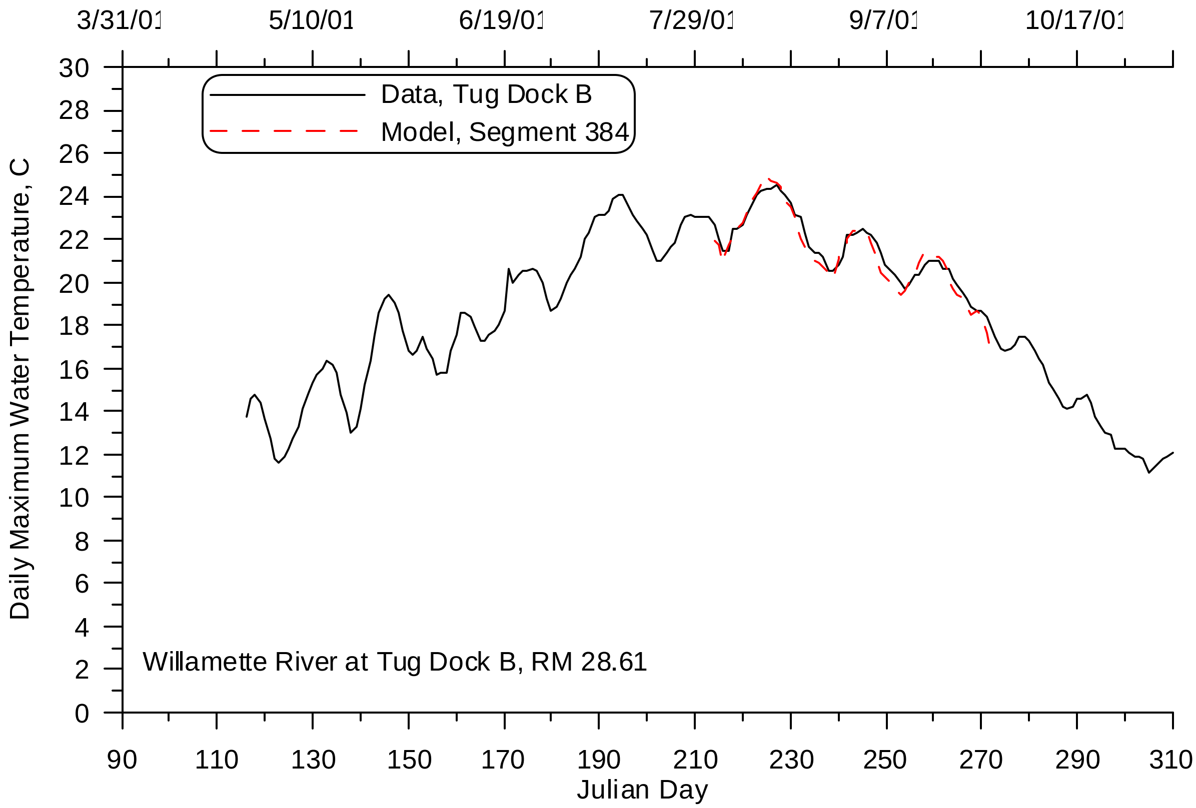

Figure 156: Willamette River at Tug Dock B model-data daily maximum temperature comparison, 2001

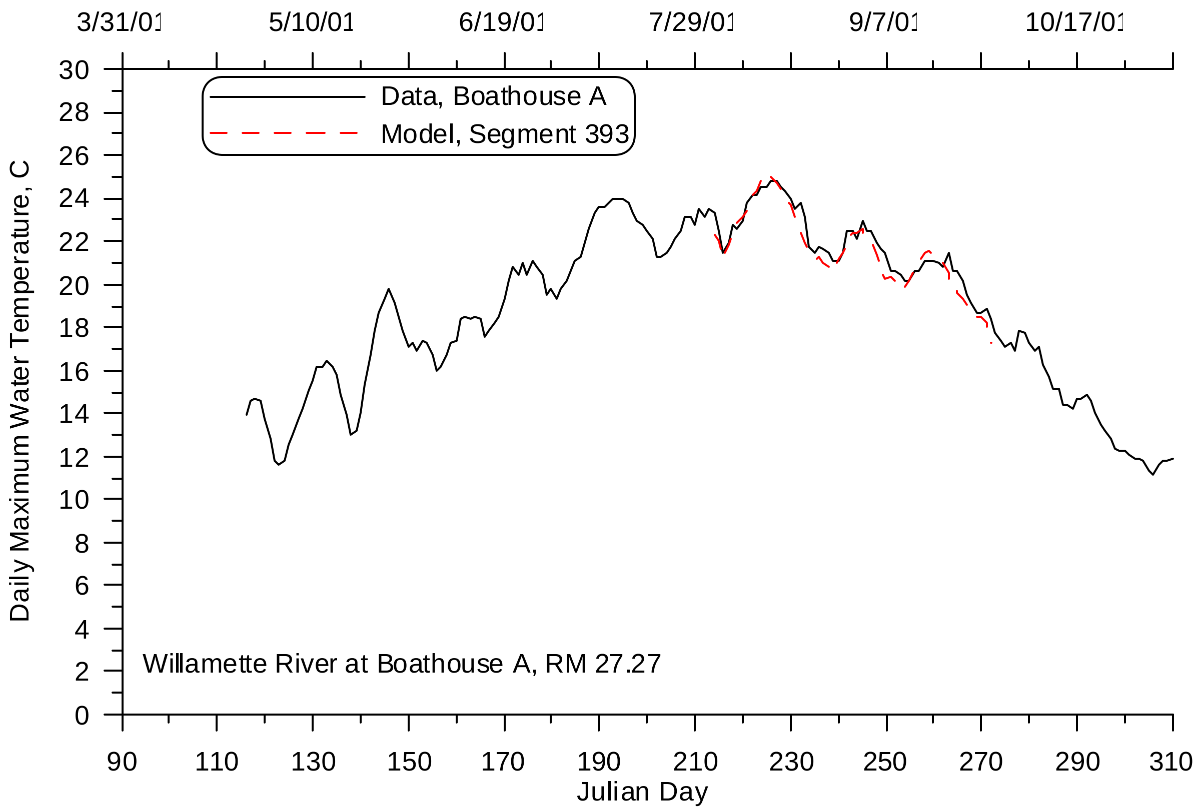

Figure 157: Willamette River at Boathouse A model-data daily maximum temperature comparison, 2001

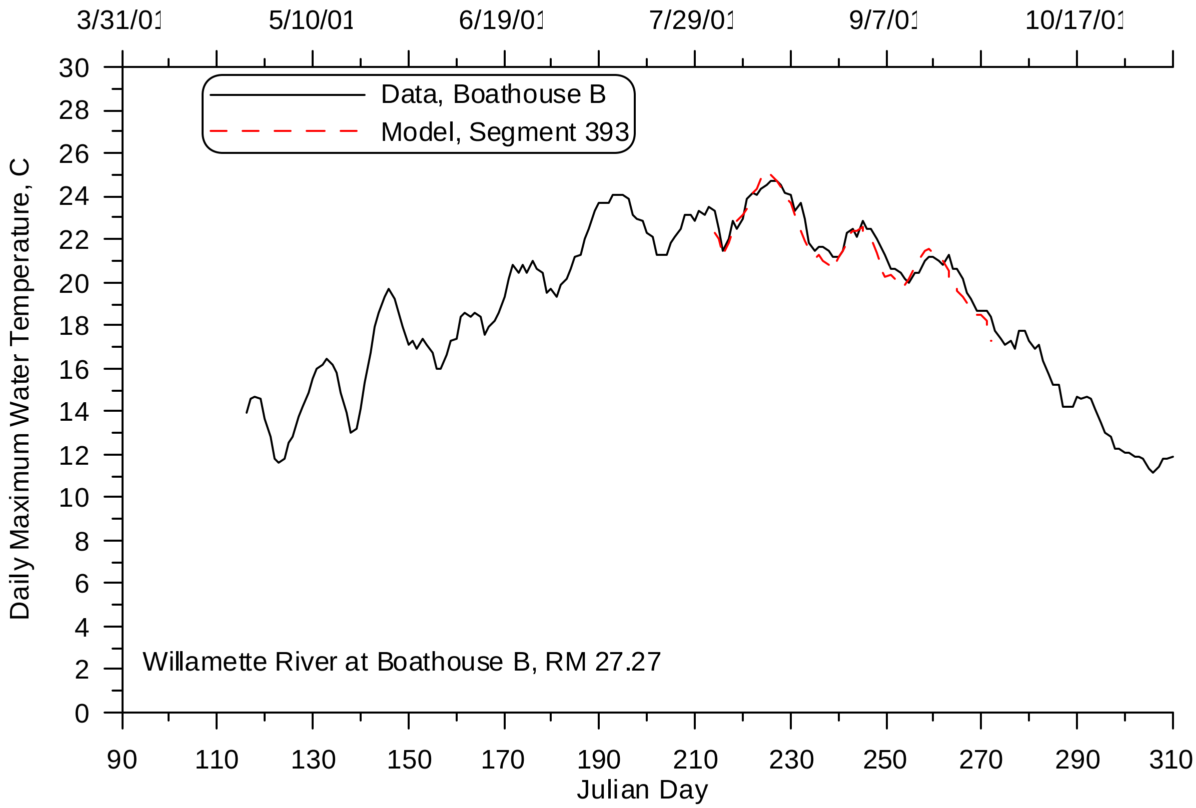

Figure 158: Willamette River at Boathouse B model-data daily maximum temperature comparison, 2001

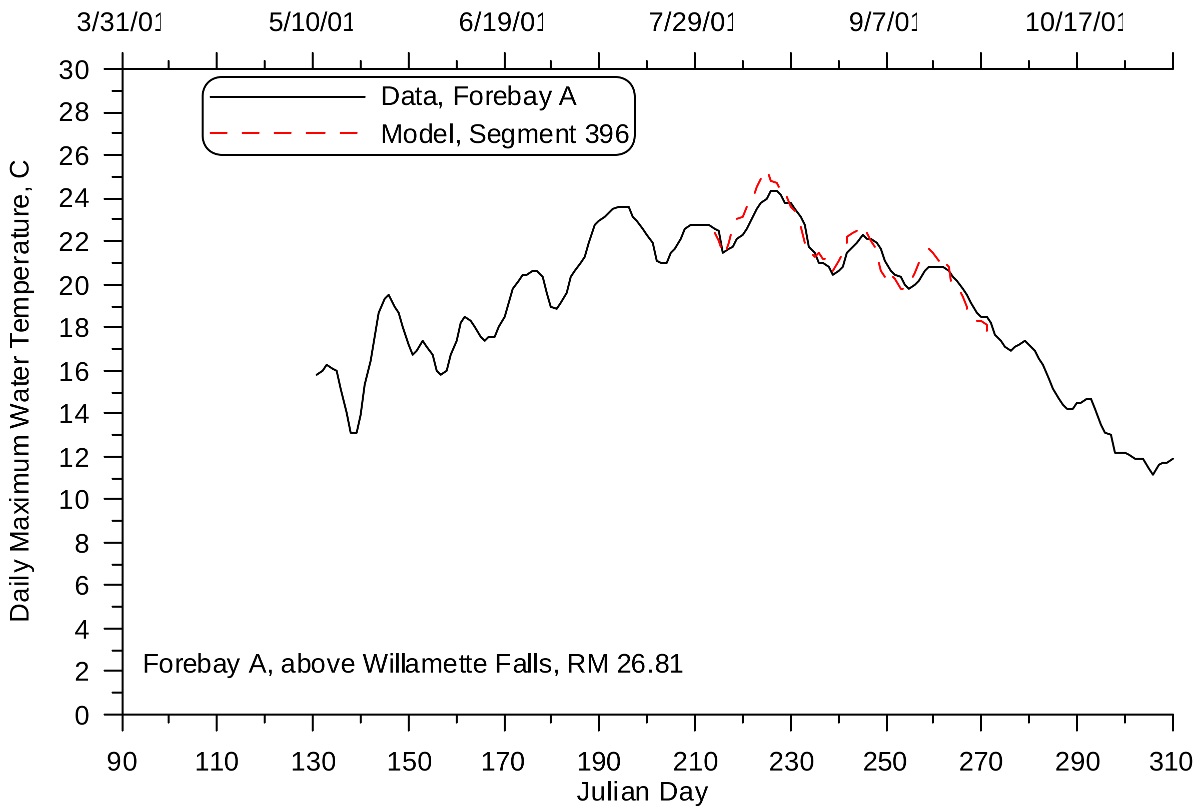

Figure 159: Willamette River at Forebay A model-data daily maximum temperature comparison, 2001

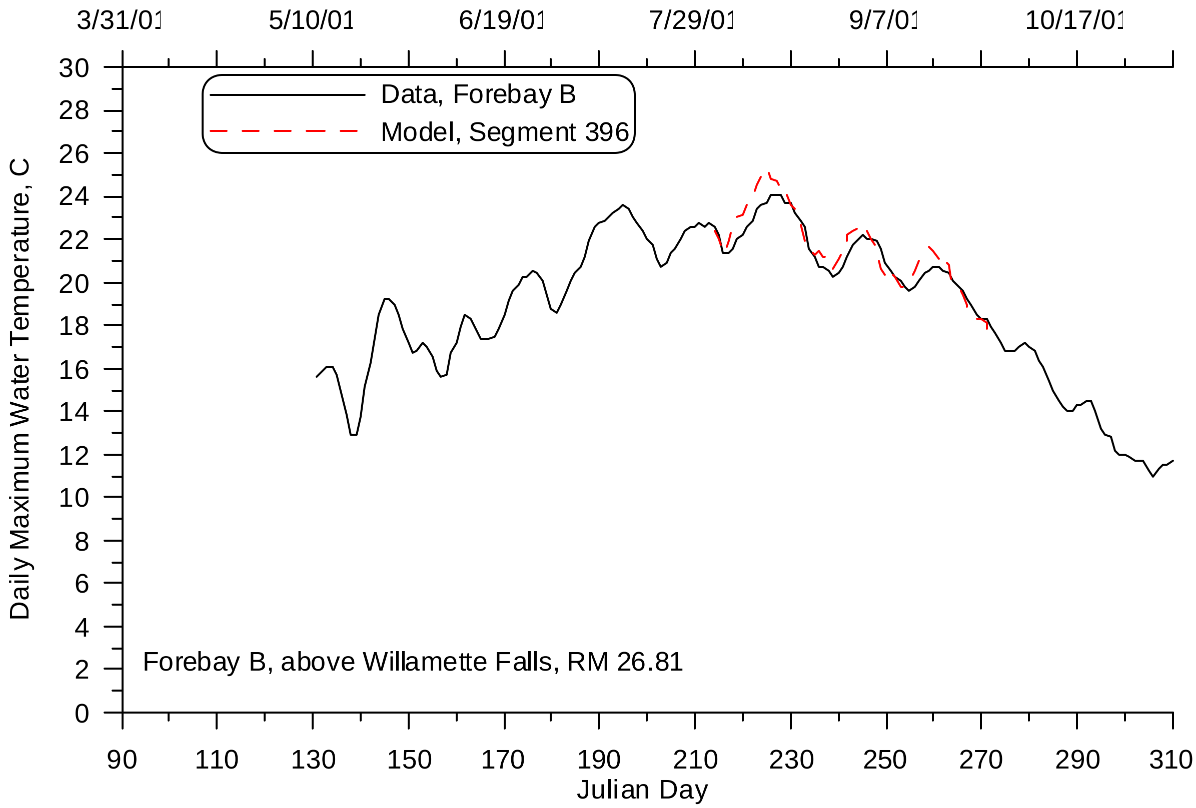

Figure 160: Willamette River at Forebay B model-data daily maximum temperature comparison, 2001

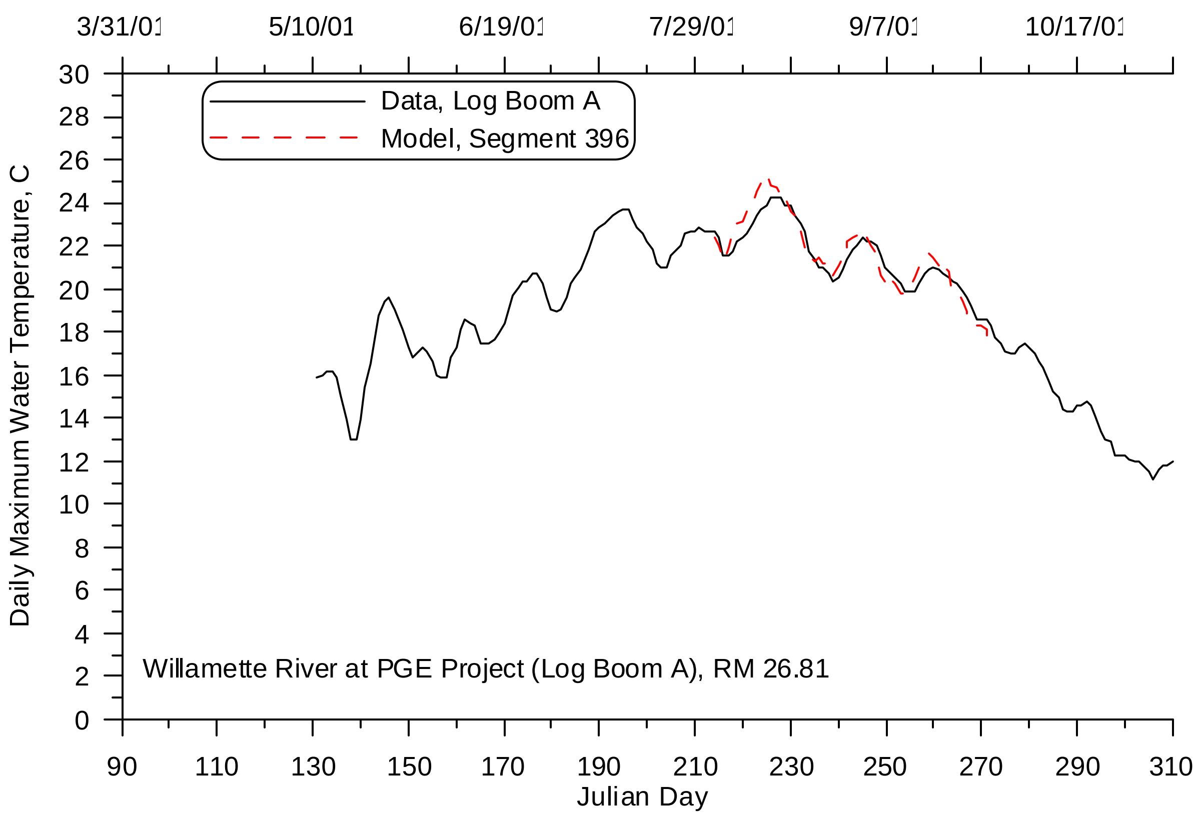

Figure 161: Willamette River at Log Boom A model-data daily maximum temperature comparison, 2001

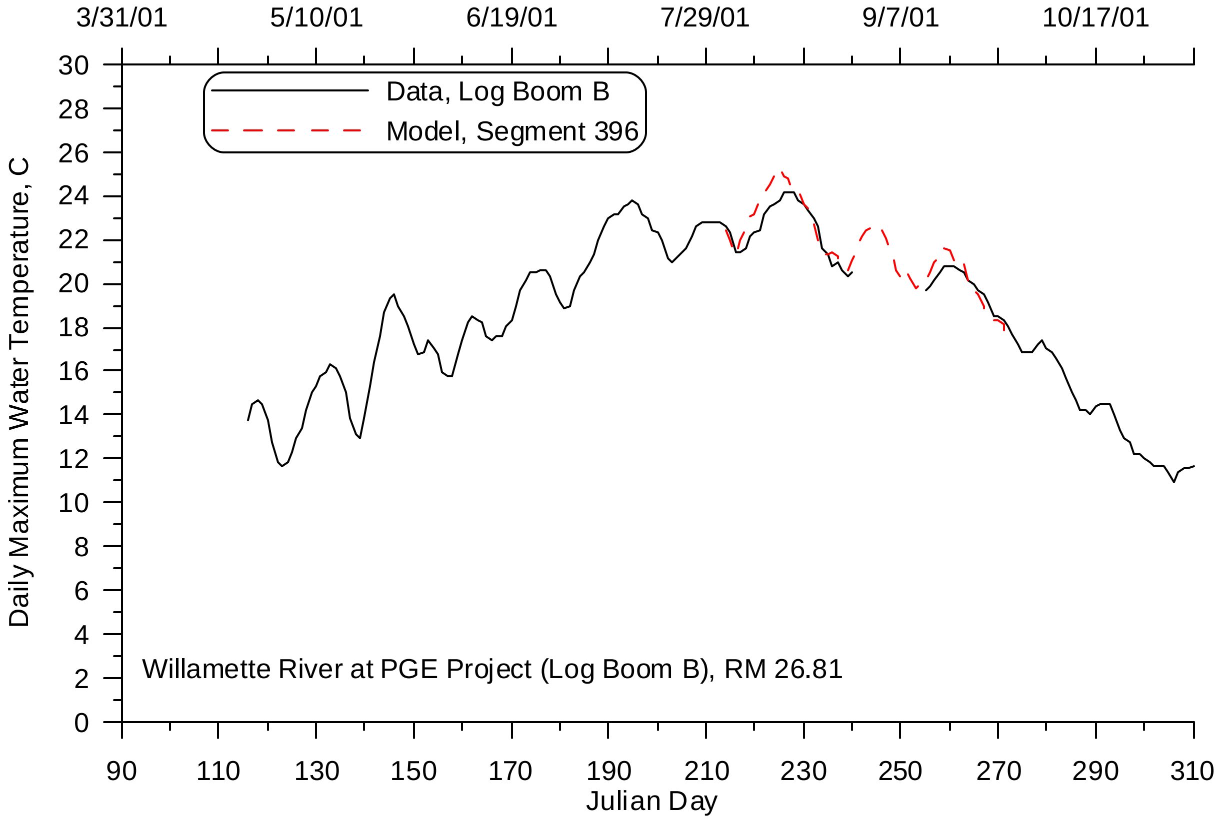

Figure 162: Willamette River at Log Boom B model-data daily maximum temperature comparison, 2001

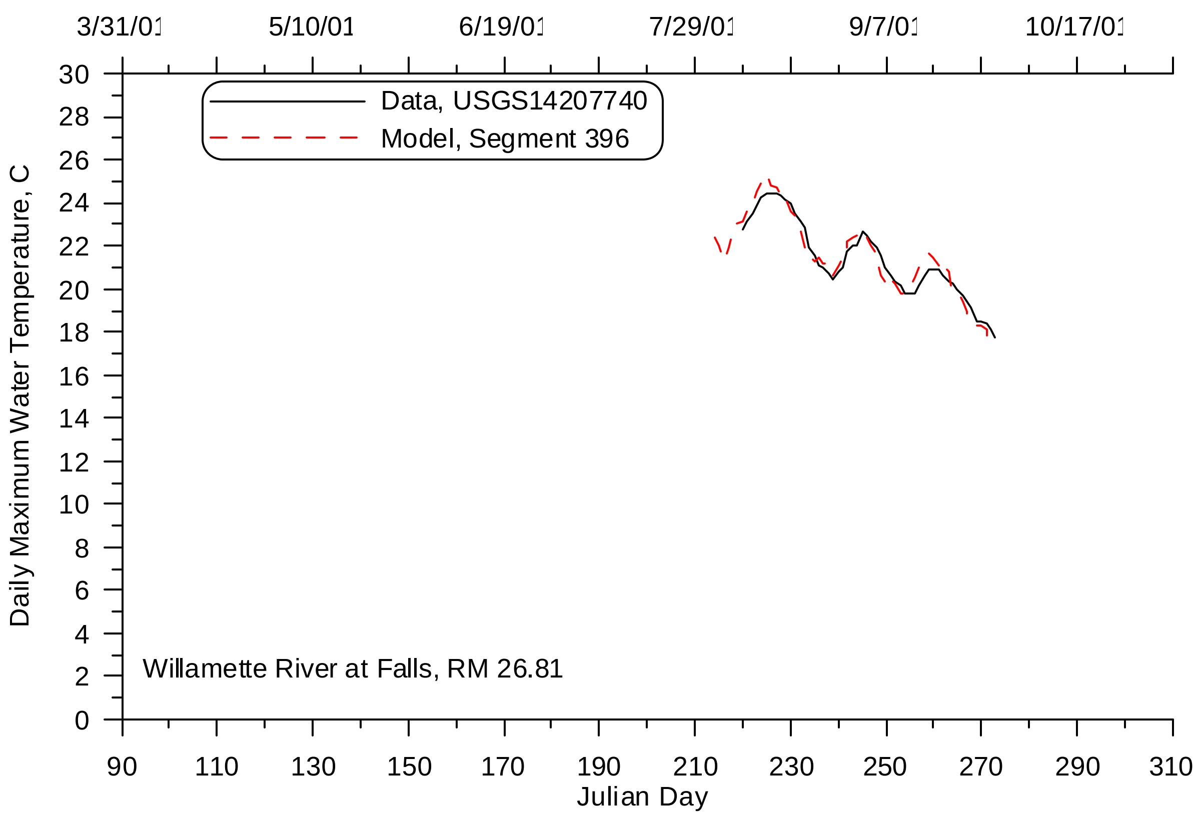

Figure 163: Willamette River at the Willamette Falls model-data daily maximum temperature comparison, 2001

Year 2002

Daily maximum temperature model-data error statistics for the 2002 Middle Willamette River model are listed in Table 19. The model-data error statistics of mean error, absolute mean error, and root mean square error are below 0.85 ^{o}C. Figure 164 through Figure 171 show comparisons of model predicted daily maximum temperature and data. The time series plots indicate there is good agreement between the model and data for daily maximum temperature with some differences in the early spring which may be due to the large flush of water in late April or inaccuracies in some of the input data in early spring. Overall the model is doing well in matching daily maximum temperatures.

Table 19: Middle Willamette River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14192015	82.60	18	183	-0.37	0.46	0.57
LASAR 28255	79.18	40	135	0.08	0.43	0.58
LASAR 10344	72.63	82	82	0.17	0.40	0.50
DEQ Coffee Island	61.51	156	156	-0.16	0.68	0.81
LASAR 30525	55.30	197	131	-0.57	0.61	0.82
USGS 14197900	50.11	246	183	0.10	0.43	0.54
LASAR 10340	38.94	318	114	-0.66	0.71	0.82
USGS 14207740	28.81	396	181	-0.25	0.50	0.62

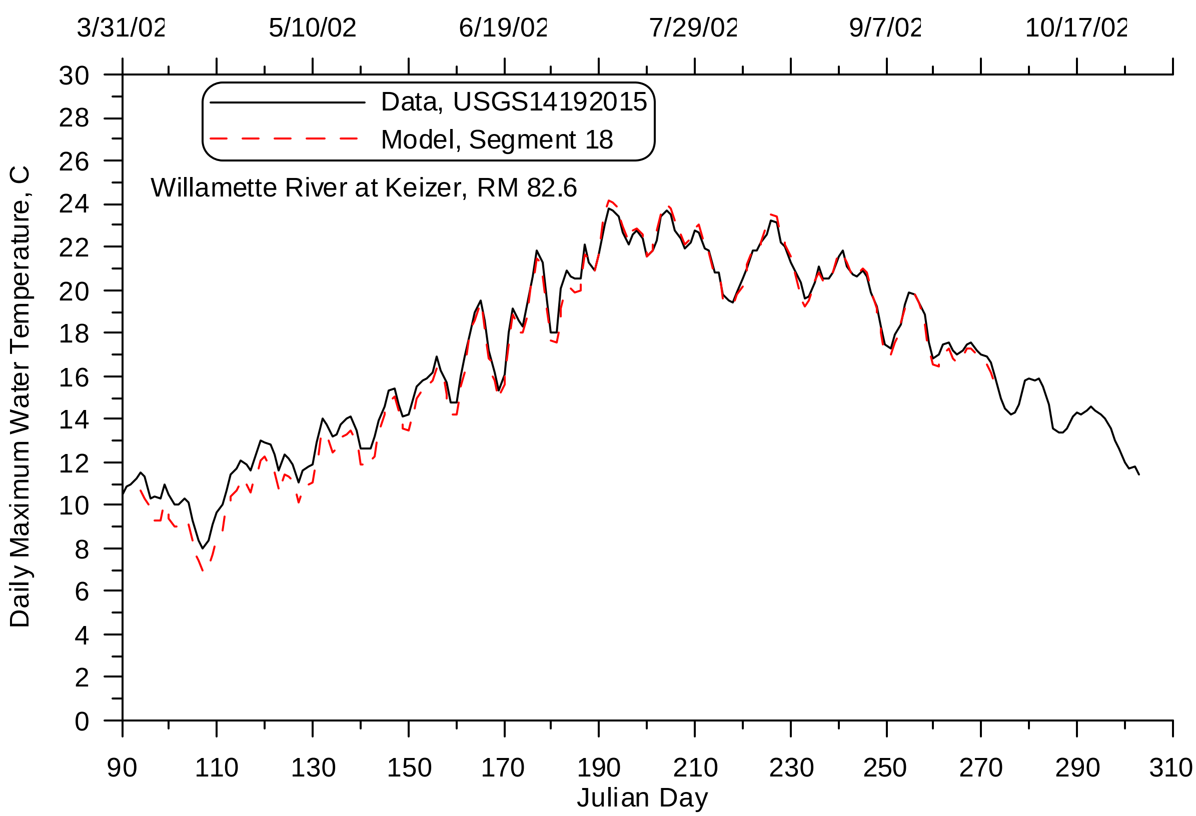

Figure 164: Willamette River at Keizer model-data daily maximum temperature comparison, 2002

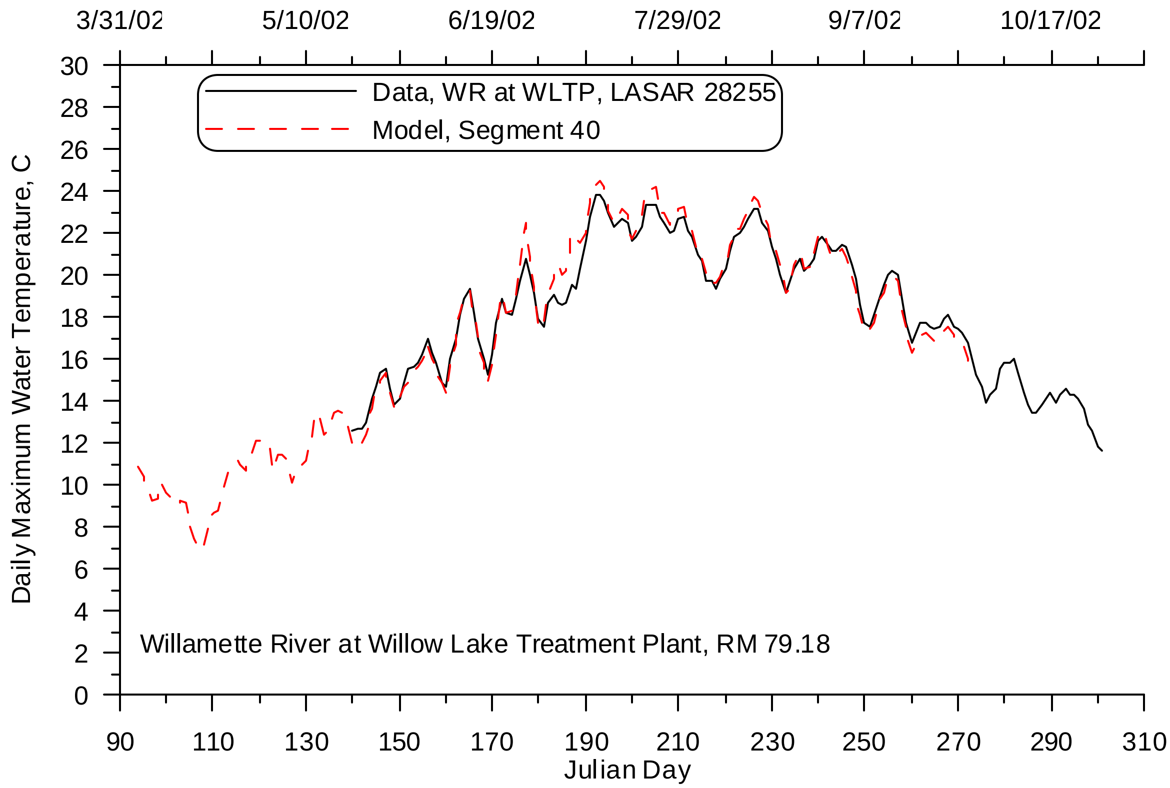

Figure 165: Willamette River at Willow Lake Treatment Plant model-data daily maximum temperature comparison, 2002

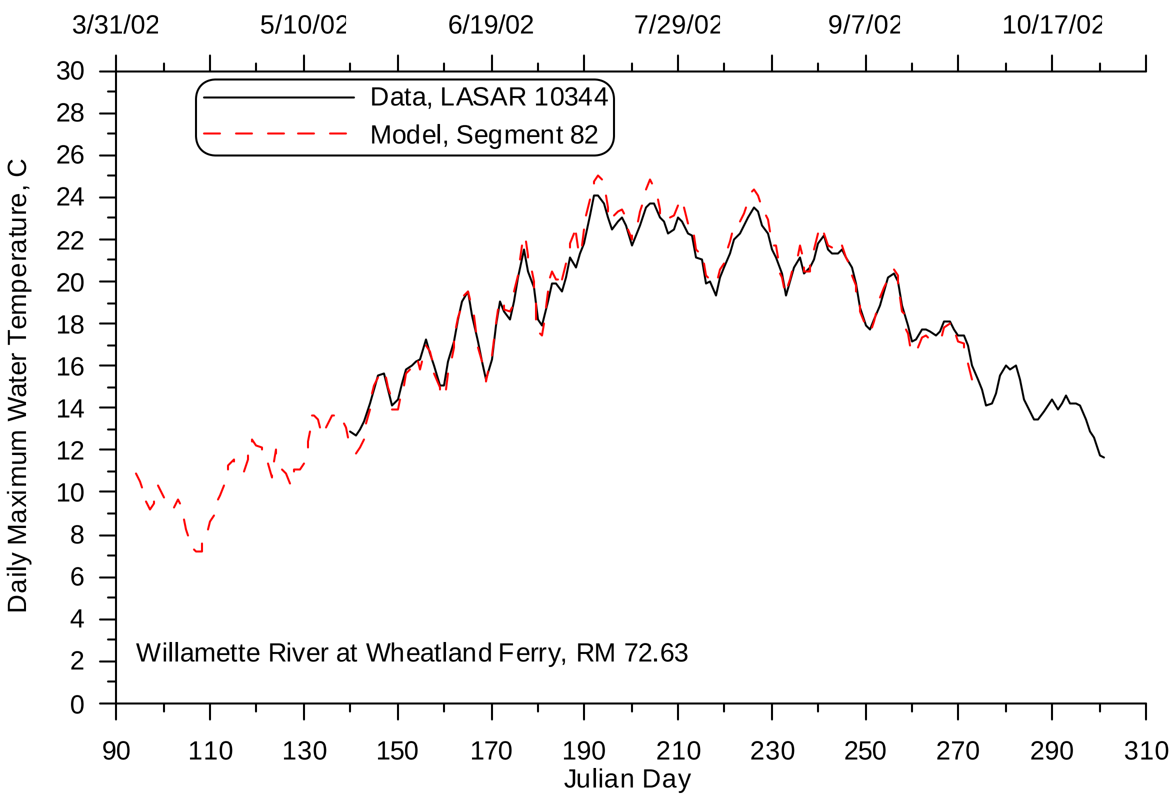

Figure 166: Willamette River at Wheatland Ferry model-data daily maximum temperature comparison, 2002

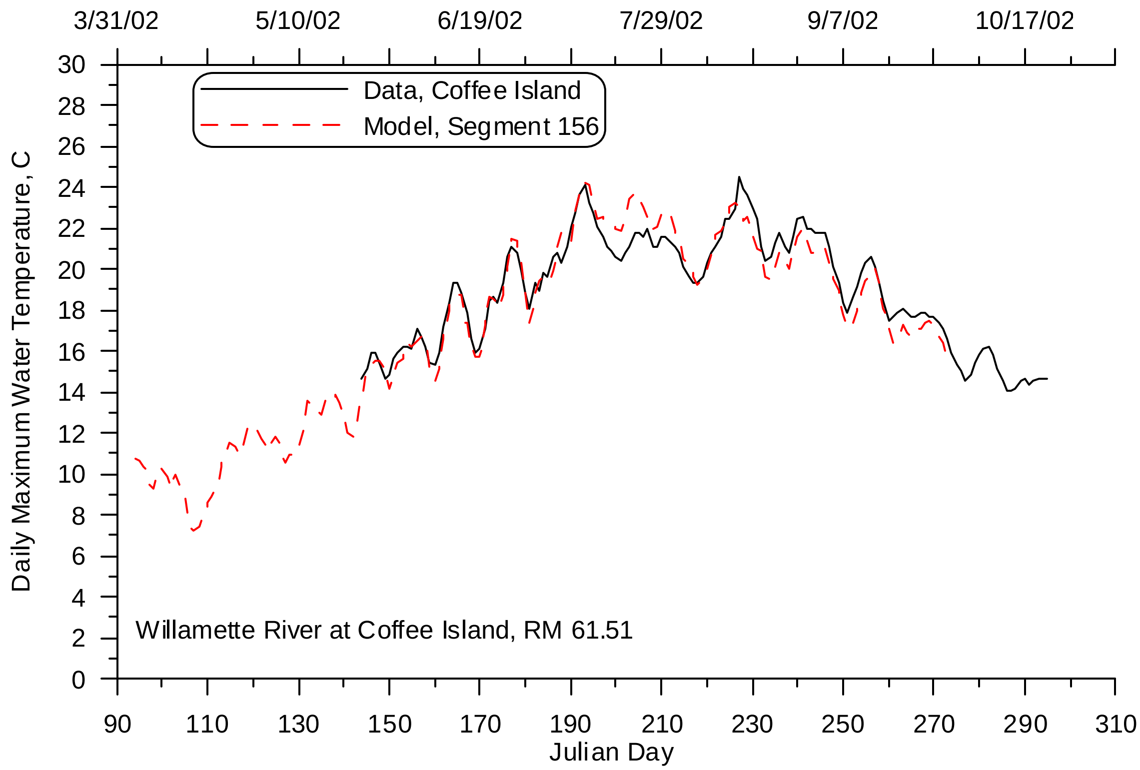

Figure 167: Willamette River at Coffee Island model-data daily maximum temperature comparison, 2002

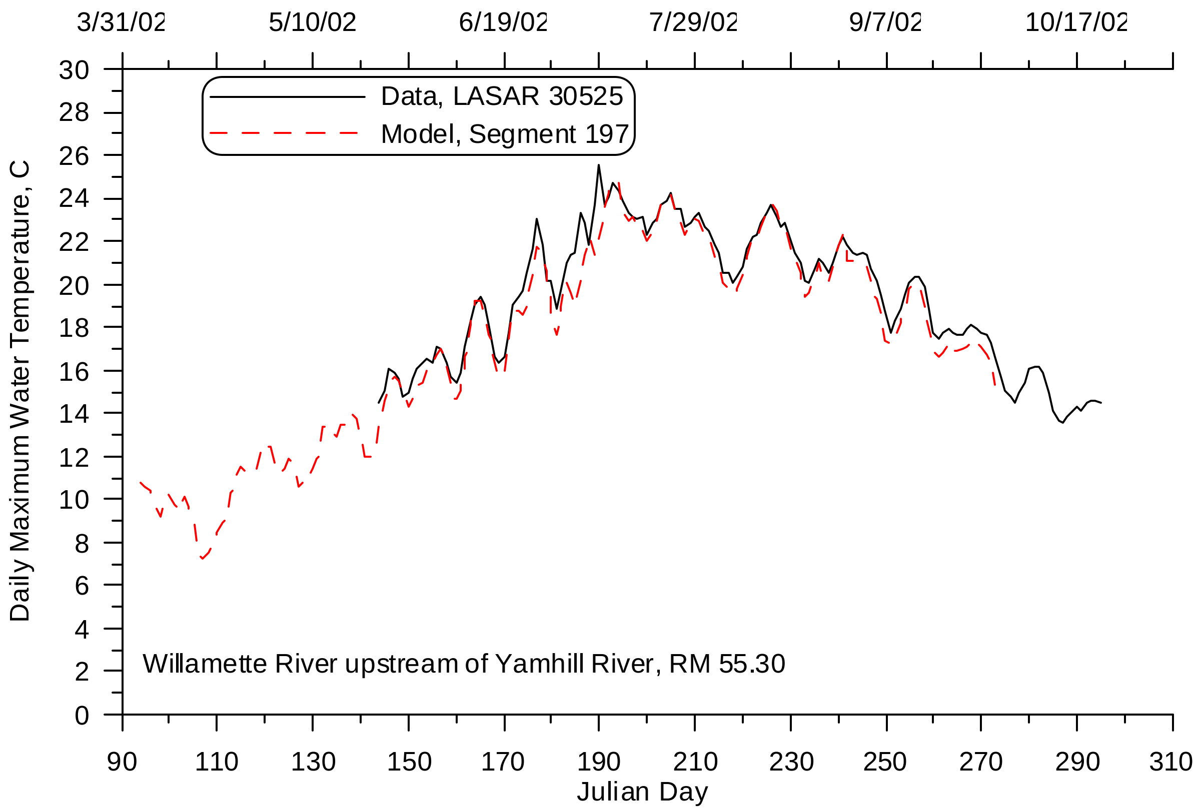

Figure 168: Willamette River upstream of the Yamhill River model-data daily maximum temperature comparison, 2002

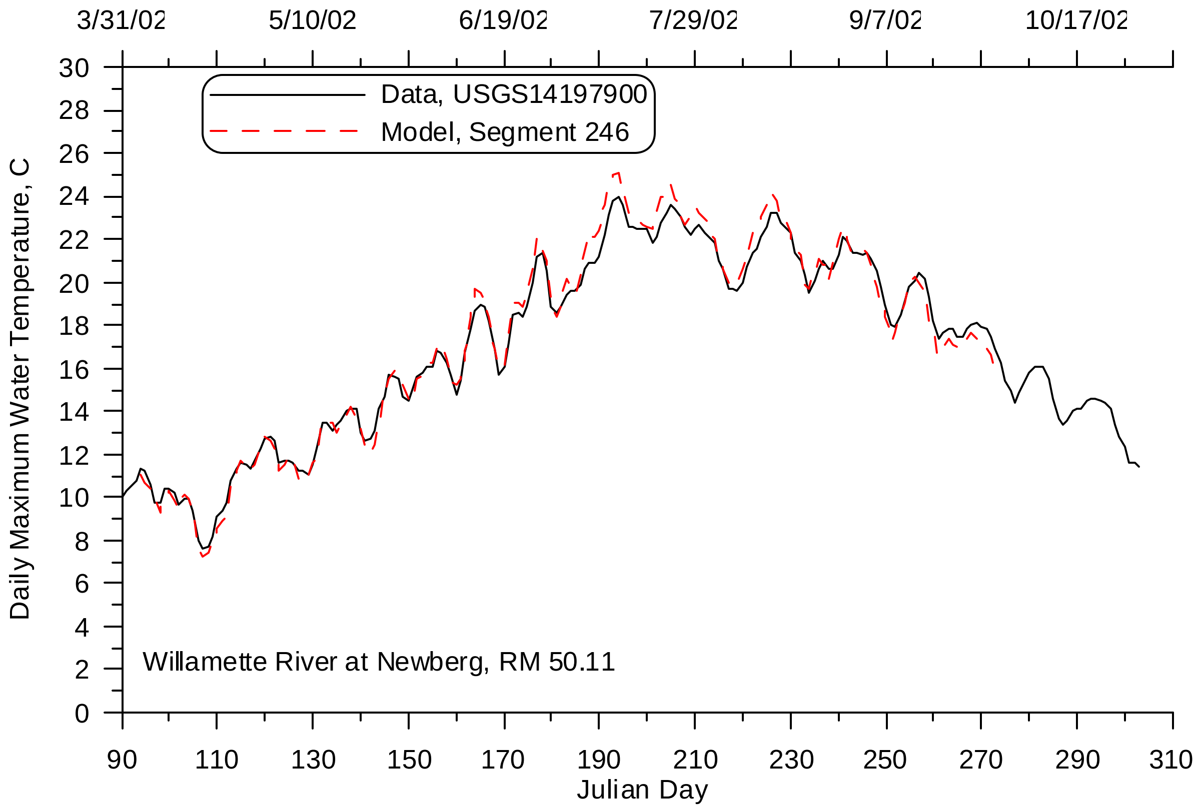

Figure 169: Willamette River at Newberg model-data daily maximum temperature comparison, 2002

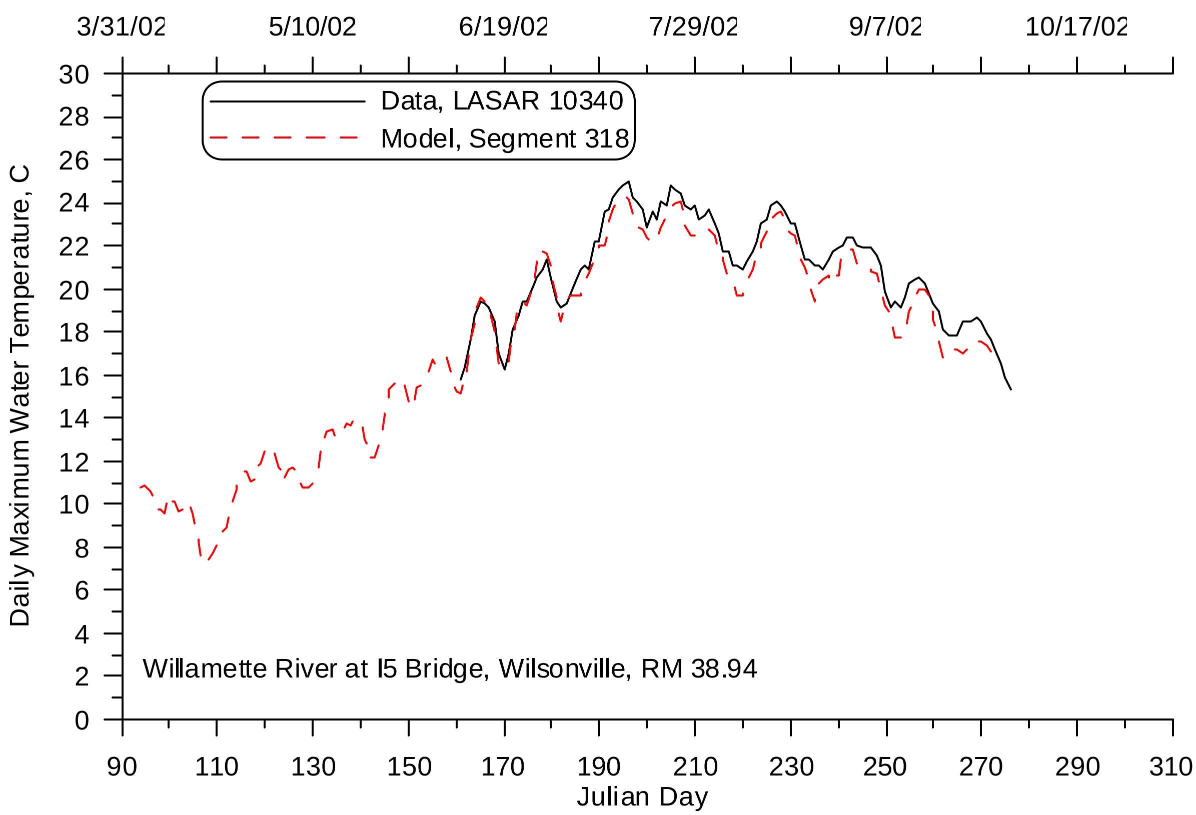

Figure 170: Willamette River at I5 Bridge, Wilsonville model-data daily maximum temperature comparison, 2002

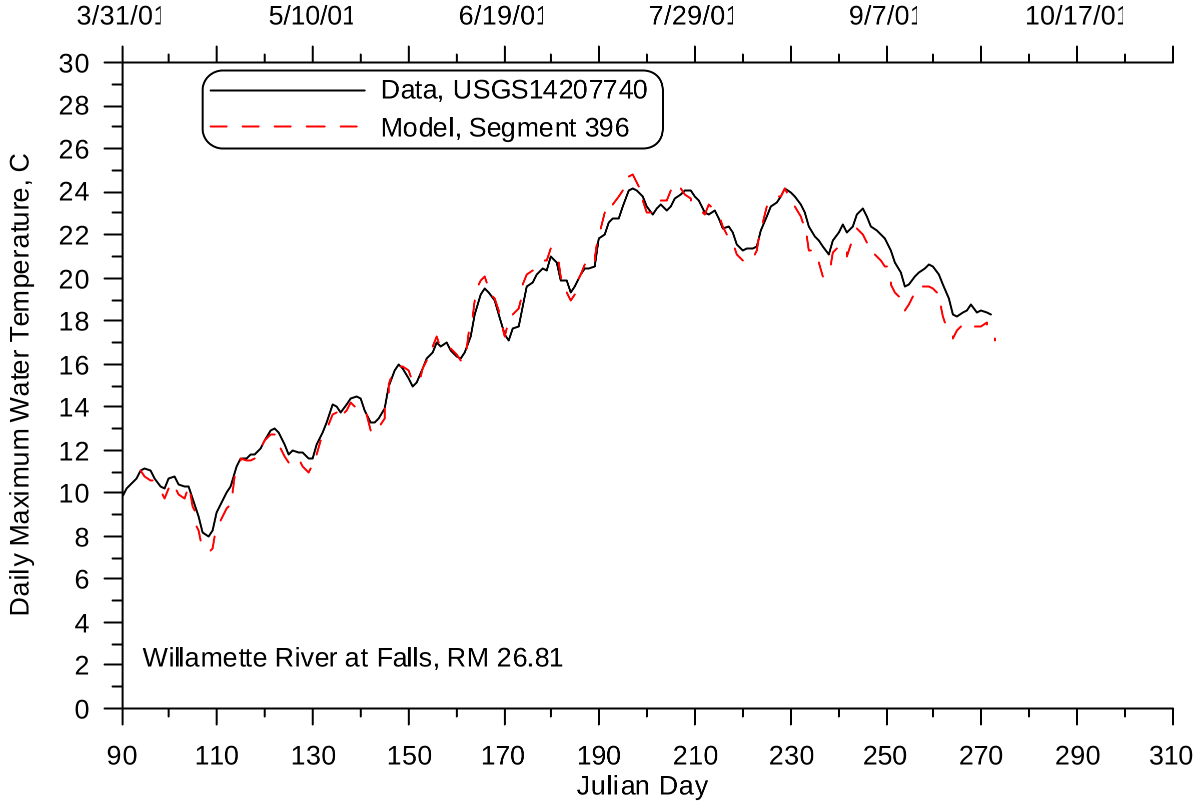

Figure 171: Willamette River at the Willamette Falls model-data daily maximum temperature comparison, 2002

Upper Willamette River

Introduction

The Upper Willamette River model starts at the City of Springfield, OR, RM 185, and ends at the City of Salem, OR, RM 85. Figure 172 shows the model area, model tributaries, and major cities. The first step of the calibration process was matching the hydrodynamic data, or flow, water surface elevation, channel wetted-width, and time of travel dye studies. The next step was to match water column temperature. This required some alteration of the bathymetry, and an iterative approach to match the hydrodynamic and temperature data.

The calibration period for the 2001 year is 6/12/2001 to 9/25/01. The starting date is limited by temperature data for the McKenzie River. The ending date is limited by temperature data for the Santiam River. The calibration period for the 2002 year is 6/4/2002 to 10/1/02. The calibration period is limited by the USBC temperature data, the Willamette River at Springfield.

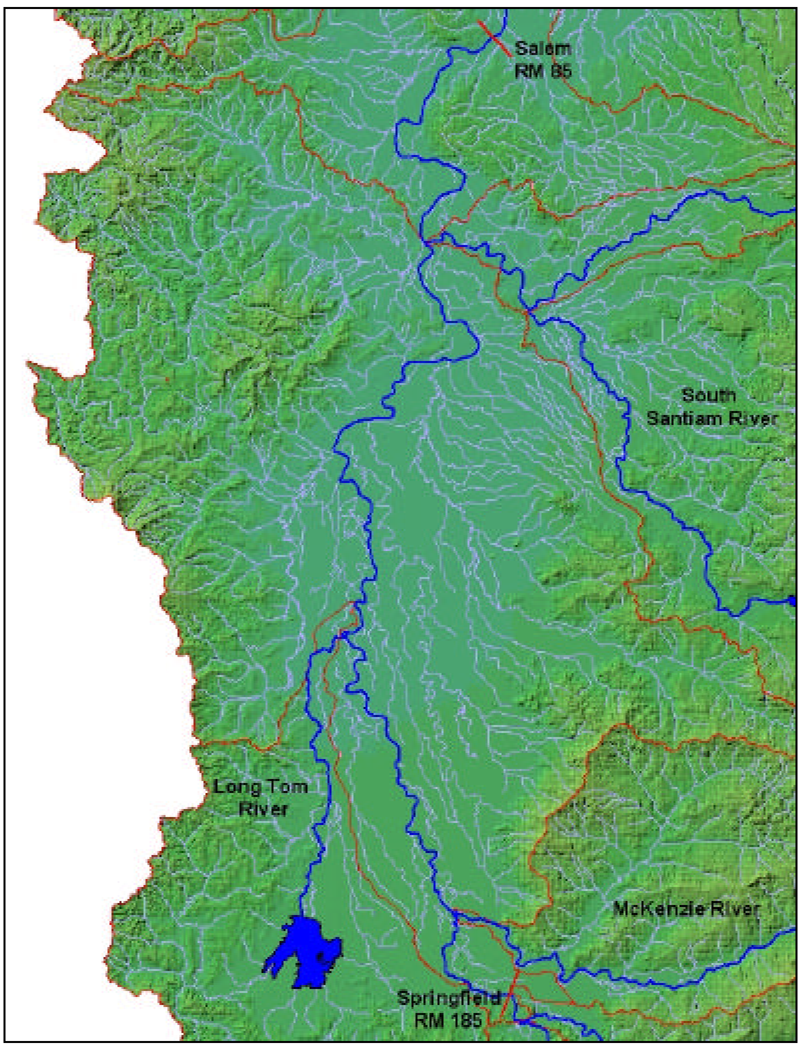

Figure 172: Upper Willamette River model region

Hydrodynamics

The hydrodynamic calibration data included continuous flow, continuous water surface elevation, time of travel dye studies, and channel width data. Model calibration adjusted the following: channel width of each model layer, channel depth (i.e., add or remove the lowest model layer), channel bottom friction, the slope of a branch, the elevation of water body (EBOT), and longitudinal dispersion.

Initial model runs focused on "running water through the system," or rather, eliminating numerical instabilities. In general, most instabilities and their solutions are summarized in Table 20.

Table 20: Upper Willamette River model hydrodynamic instabilities and solutions

Cause of Instability	Typical Solution
Rapidly changing lowest active grid segment.	The grid bottom is smoothed by adding or removing narrow bottom grid cells.
Rapidly changing segment width usually pinches.	A single narrow segment is widened. For multiple narrow segments, the changing width is tapered.
Model "dries up."	Increase channel friction, or identify pinch in the upstream flow which is ponding water.
Notably different channel bottom elevations at branch connection.	Smooth the connection: 1) Add or remove bottom grid cells near the branch connection; 2) Adjust channel slope and channel elevation (EBOT).

Concurrent to eliminating model instabilities, the timing of the continuous flows were calibrated. The channel friction was sufficiently sensitive to adjust the flow timing.

Moving downstream, a water balance was conducted at each flow calibration point. The resulting calibration flow was then incorporated into the distributed tributary flows. The flow was apportioned by model length to the branches between the flow calibration points. The calibration flows were time-lagged using a representative travel time from the center of the branch to the downstream calibration point. The resulting calibration flows were then added to the existing distributed flows. This process was repeated if the new flows were a poor calibration.

Once the magnitude of flow at a calibration point was calibrated, the water surface elevation was examined. For small changes, the channel width could be adjusted. For large changes, such as a meter or more, the water body bottom elevation (EBOT) was adjusted. Any change in EBOT required a careful examination of the resulting branch connection. It was necessary to adjust slope slightly to maintain feasible branch connections. For cases when the water level was accurate at a low or high flow regime, but not accurate at a different flow regime, altering the channel width for the appropriate layer was the most effective solution. In all cases, any alteration of channel width was tapered into the upstream and downstream segments.

After flow magnitude, flow timing, and water surface elevation were roughly calibrated, the 1968 Harris study time of travel data was examined. A separate model was generated which utilized a single upstream tributary, and no tributaries or distributed tributaries. For five different flow magnitudes, the flow was allowed brought to near steady-state and the travel time recorded. The results were converted to travel rates and compared to the discharge-travel rate curves of the Harris study. Channel bottom friction adjustments are the removal of some bathymetric pinches slowing flow brought the flow rates into rough calibration.

Wetted width data provided by ODEQ was then examined. At the flows associated with the wetted width data, the model surface layer was identified and the cell widths at all layers were potentially adjusted to match the data. After matching the widths, flow magnitude and timing and water surface elevation were reexamined to ensure that they were still calibrated. At this point the hydrodynamics were largely calibrated except for the individual reaches over which recent dye study data was available. Temperature calibration determined the major bathymetric changes from this point. Bathymetry changes due to temperature primarily included changing the depth over a reach to alter residence time and/or change the volume of water undergoing heating and cooling over a reach. Hydrodynamic calibration was periodically checked and adjusted.

Five stations monitoring river stage and discharge were used in model calibration. Table 21 lists the hydrodynamic gaging stations and the respective river mile and model segment. While the station at Salem, USGS 14191000, records stage, the station is outside the model area, approximately 750 m downstream of the last model segment. The station locations are shown in Figure 173. Hydrodynamic calibration of years 2001 and 2002 was a simultaneous process.

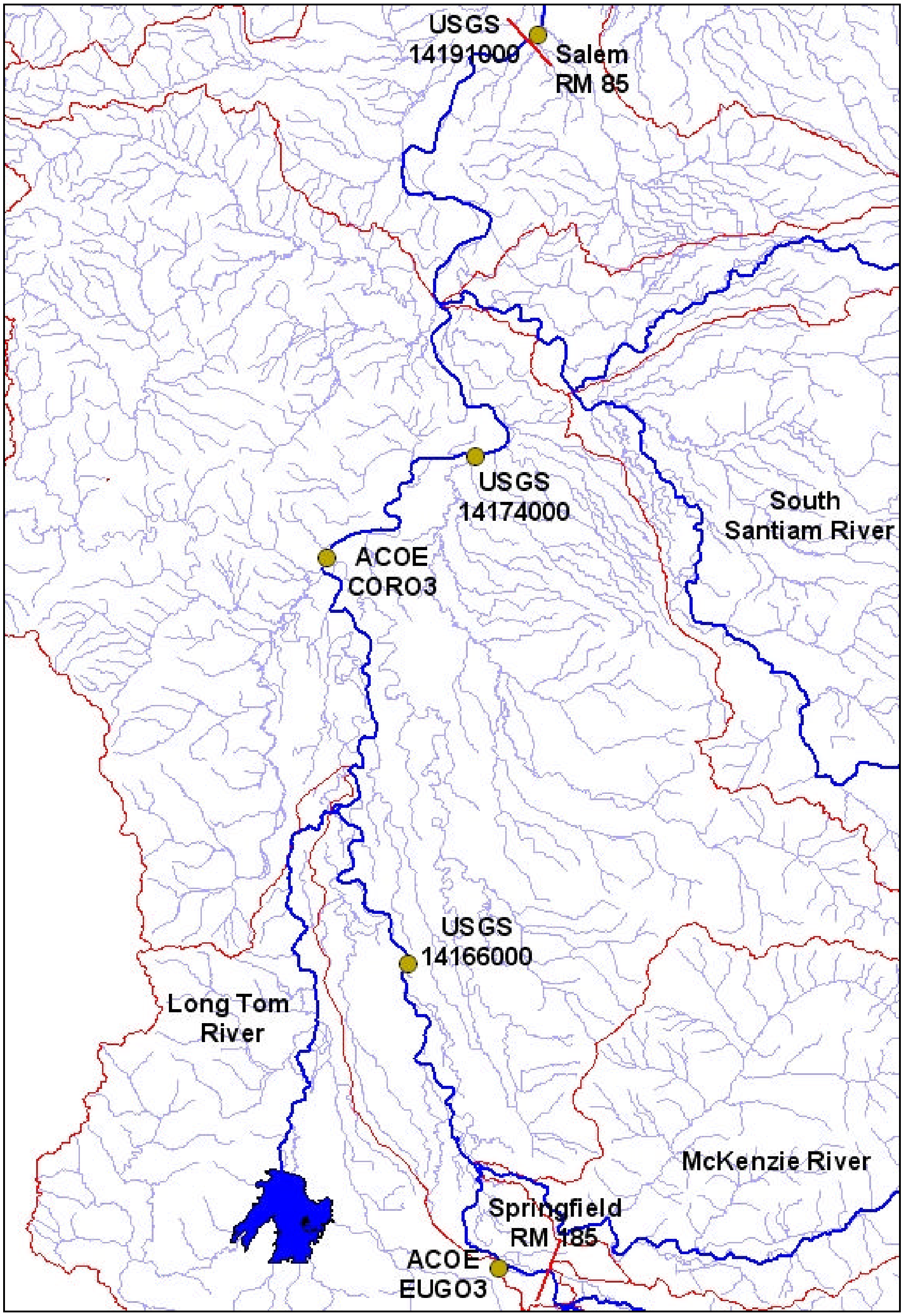

Figure 173: Upper Willamette River hydrodynamics calibration site locations

Table 21: Upper Willamette River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USACOE EUGO3	Willamette River at Eugene	182.45	19	Q & WL
USGS 14166000	Willamette River at Harrisburg	161.98	156	Q & WL
USACOE CORO3	Willamette River at Corvallis	132.32	343	Q & WL (2002)

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14174000	Willamette River at Albany	120.11	432	Q & WL
USGS 14191000	Willamette River at Salem	84.70	666	Q

Flow and Water Surface Elevation

Model flow timing was calibrated by adjusting channel bottom friction and removing a few pinches in the bathymetry. Flow magnitude was adjusted using a computer routine which performed a mass (water) balance for each flow data point. The difference in flow was applied to the distributed tributary flow with a time-lag equal to the travel time from the center of the branch to the calibration point for a representative flow. Flow magnitude and timing were largely insensitive to subsequent changes in channel bottom roughness, channel slope, channel width, and channel depth.

Small adjustments to the water surface elevation were made by adjusting the segment width over all active layers for the target segment and several up and downstream segments. Small (<20 cm) adjustments to the water surface elevation were also using the water body bottom elevation (EBOT) when only a vertical shift was required. Large adjustments in EBOT were made for two water bodies. Water body 1 was lowered 3.1 m to match water surface elevation data at Eugene and provide numerical stability at the connection with water body 2. Slope was not changed. Water body 3 was lowered 1.0 m to provide numerical stability at the water body 3 to 4 connection. The slope over water body 3 was steepened to maintain the upstream segment elevation. Model water surface elevations were sensitive to subsequent changes in channel bottom roughness, channel width, and channel depth, but not channel slope.

Due to the length of the branches, channel slope was not an effective calibration tool due to the channel elevation constraints at both ends. A very small change in channel slope (0.01%) often results in a 1 m change in upstream elevation.

The furthest downstream hydrodynamic calibration site (USGS 14191000, Willamette River at Salem) is physically located roughly 1 km downstream from the end of the model grid. Flow was compared at this gage, but not water surface elevation, refer to Table 22 and Table 23. Flow and water surface elevation calibration of years 2001 and 2002 was a simultaneous process.

<u>Year 2001</u>

The rating curve for the gage station at Harrisburg (USGS 14166000) changed between the years 2001 and 2002. The model was calibrated for stage at Harrisburg using 2002 data.

The 2001 stage data at Corvallis, USACOE CORO3, lacks the data “noise” characteristic of the upstream and downstream stations, as well as the 2002 stage data at Corvallis. The quality of the 2001 stage data at Corvallis is questionable, so a discharge data set was not generated.

The accuracy of the stage and flow data at Albany for roughly June 1 to August 21, 2001 are known to be up to 10% in error due to problems with the gage (Based on a conversation with USGS staff, Portland OR).

Calibration statistics for the 2001 hydrodynamic stations are shown in Table 22. Errors in flow magnitude are within 1.1 m^3/s, roughly 1% of the flow magnitude. Errors in water surface elevation are within 0.23 m. The largest error is for the data at Harrisburg and Albany. The calibration for the 2001 data at these stations was given secondary priority to the 2002 water surface elevation calibration.

Table 22: Upper Willamette River hydrodynamic calibration statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
ACOE EUGO3	182.45	19	5032	0.23	0.49	0.70
USGS 14166000	161.98	156	5040	-0.21	0.46	0.62
ACOE CORO3	132.32	352	1728	Quality of data is questionable		
USGS 14174000	120.11	434	4683	0.19	0.89	1.14
USGS 14191000	84.70	665	5040	0.01	0.40	0.55
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
ACOE EUGO3	182.45	19	5032	-0.04	0.05	0.05
USGS 14166000	161.98	156	5040	0.23	0.23	0.23
ACOE CORO3	132.32	352	1728	-0.06	0.07	0.08
USGS 14174000	120.11	434	4683	-0.13	0.13	0.14
USGS 14191000	84.70	665	5040	Not appropriate comparison, 1 km downstream of model grid		

Plots of 2001 model-data comparisons are shown for flow and water surface elevation at Eugene in Figure 174 and Figure 175; for flow and water surface elevation at Harrisburg in Figure 176 and Figure 177; for water surface elevation at Corvallis in Figure 178; for flow and water surface elevation at Albany in Figure 179 and Figure 180; and for flow at Salem in Figure 181.

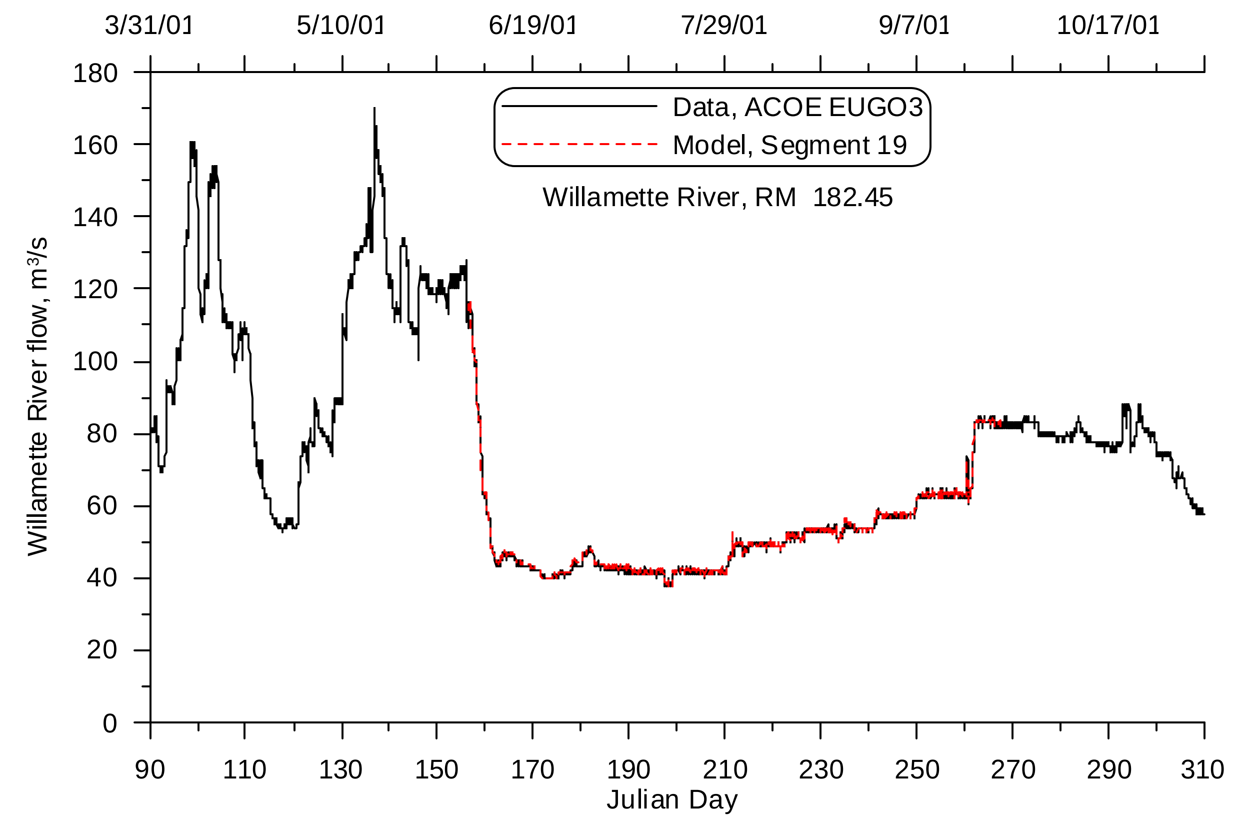

Figure 174: Willamette River at Eugene model-data flow comparison, 2001

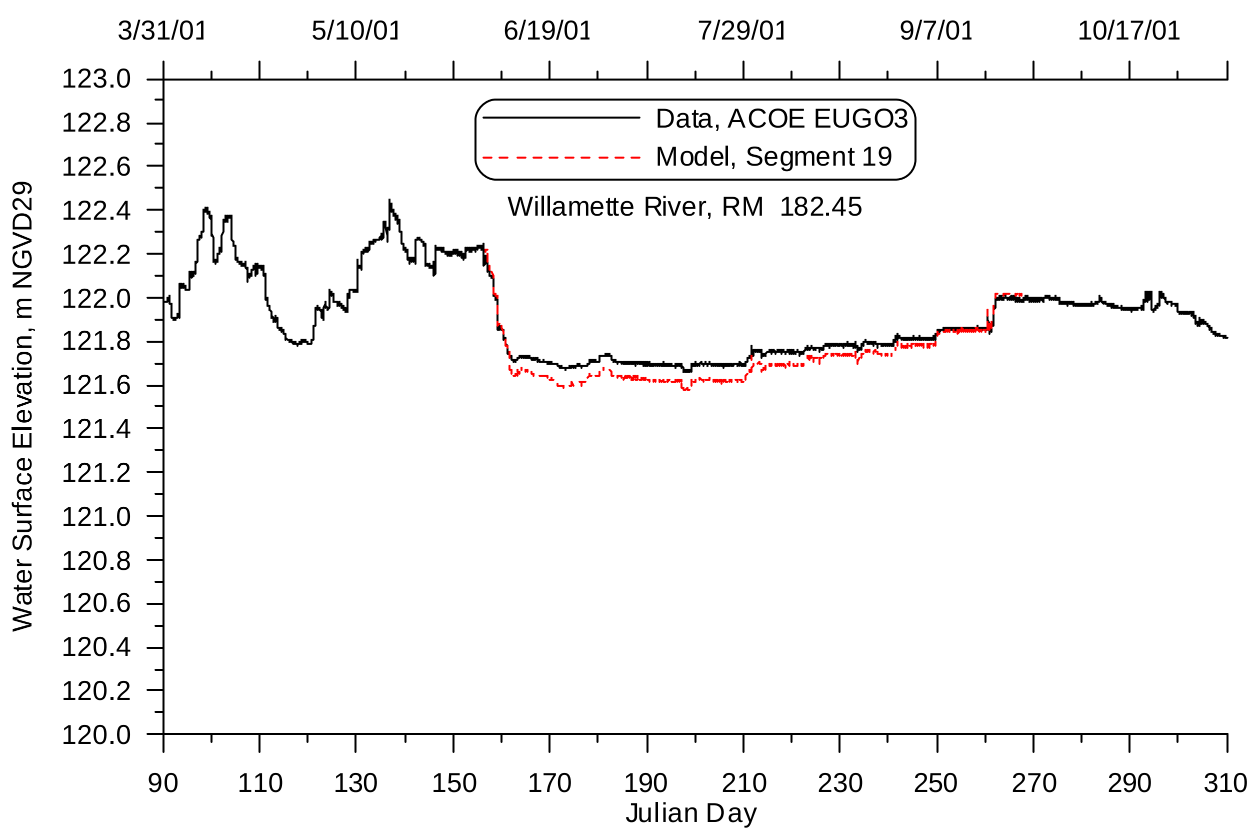

Figure 175: Willamette River at Eugene model-data water level comparison, 2001

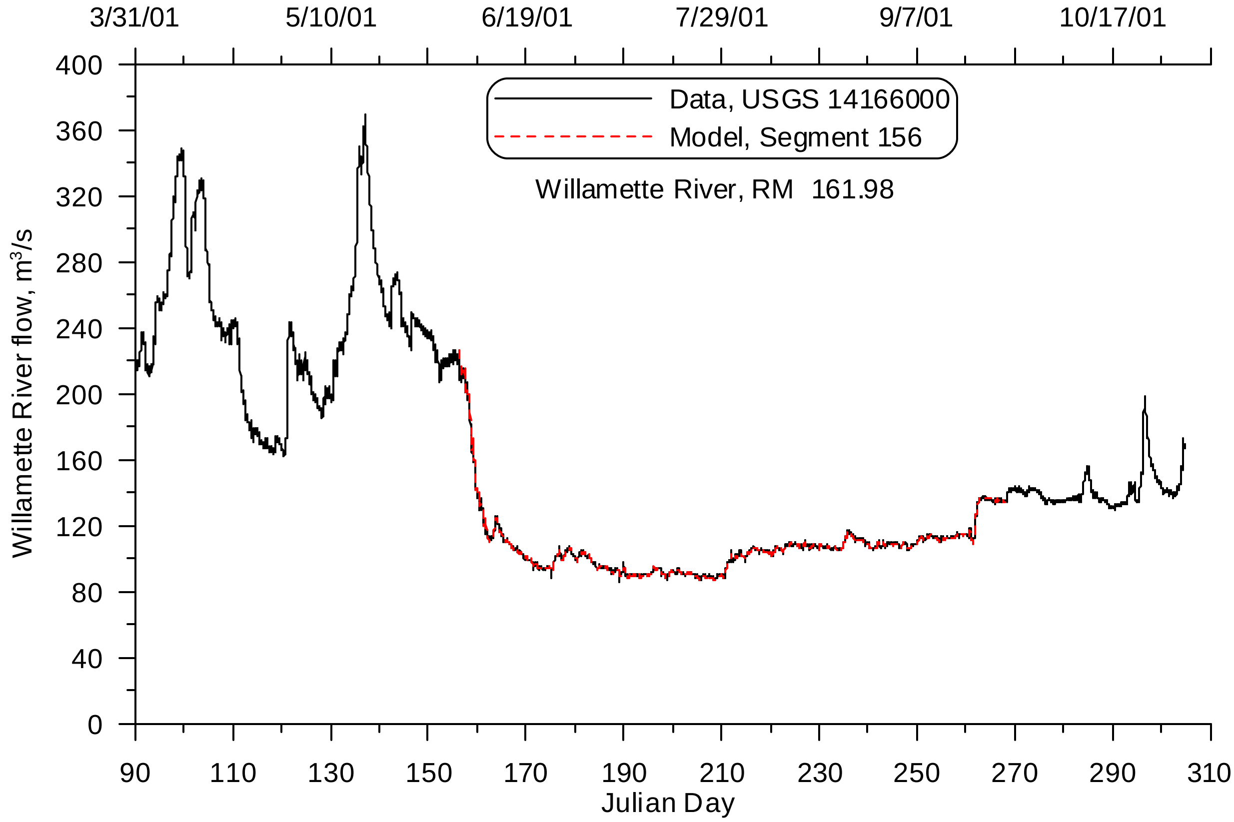

Figure 176: Willamette River at Harrisburg model-data flow comparison, 2001

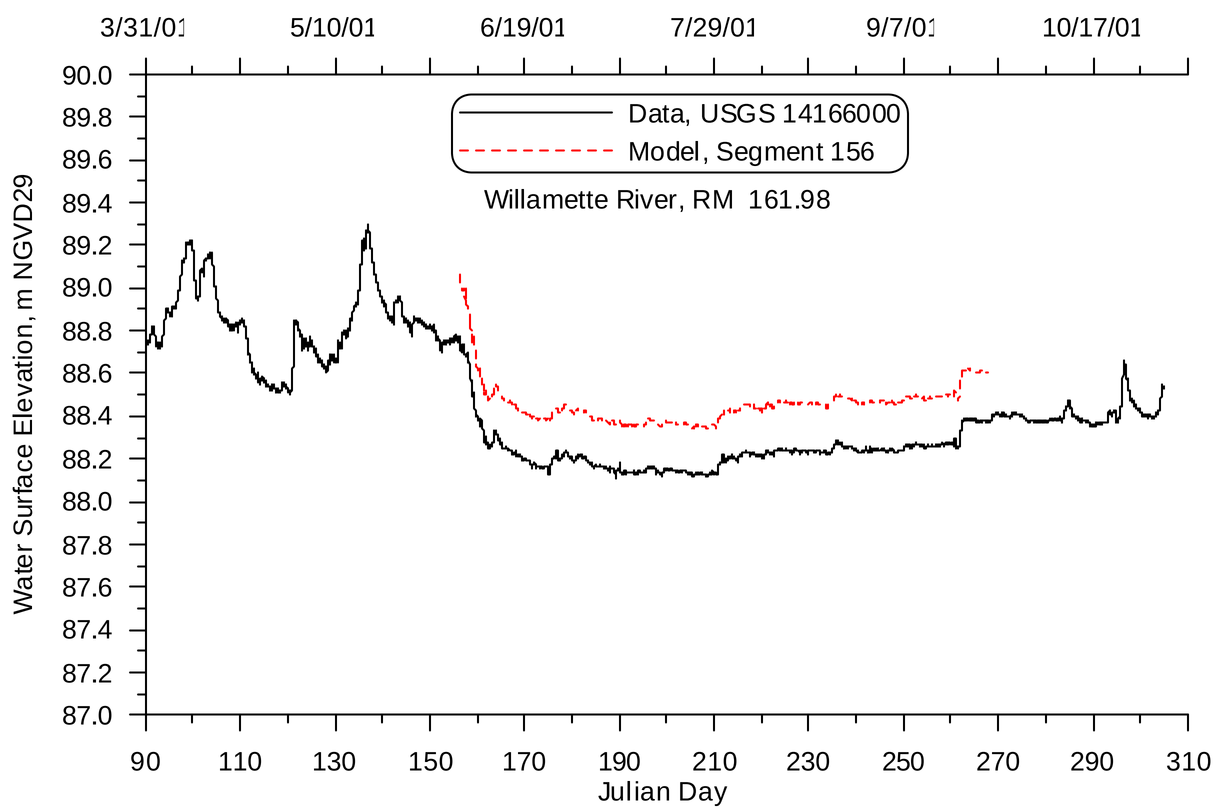

Figure 177: Willamette River at Harrisburg model-data water level comparison, 2001

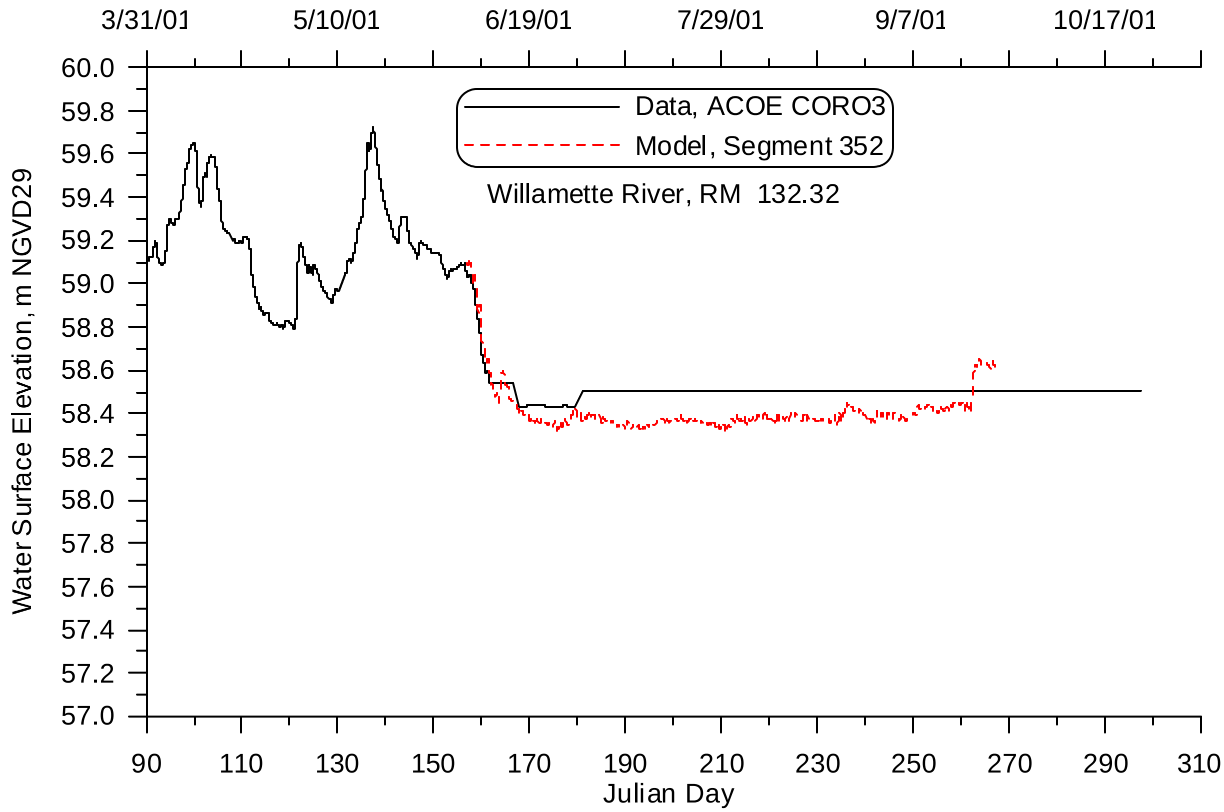

Figure 178: Willamette River at Corvallis model-data water level comparison, 2001

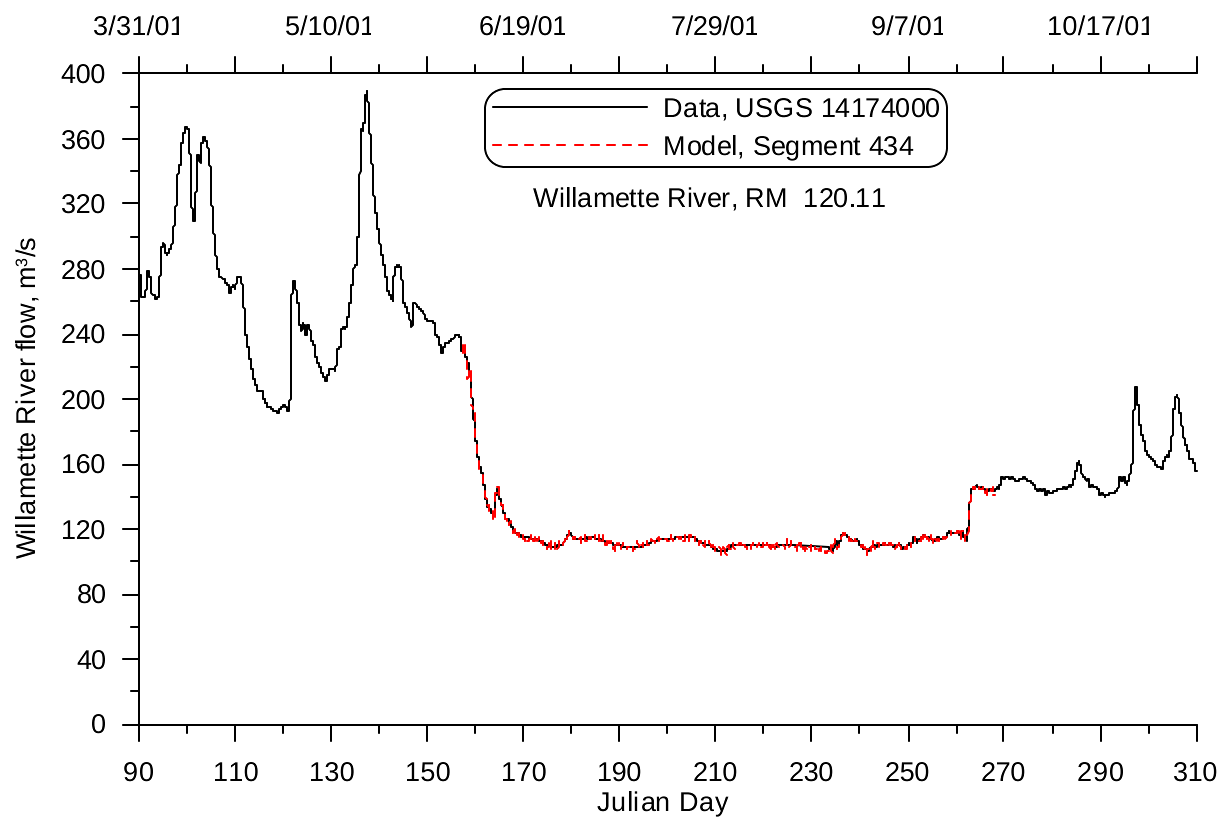

Figure 179: Willamette River at Albany model-data flow comparison, 2001

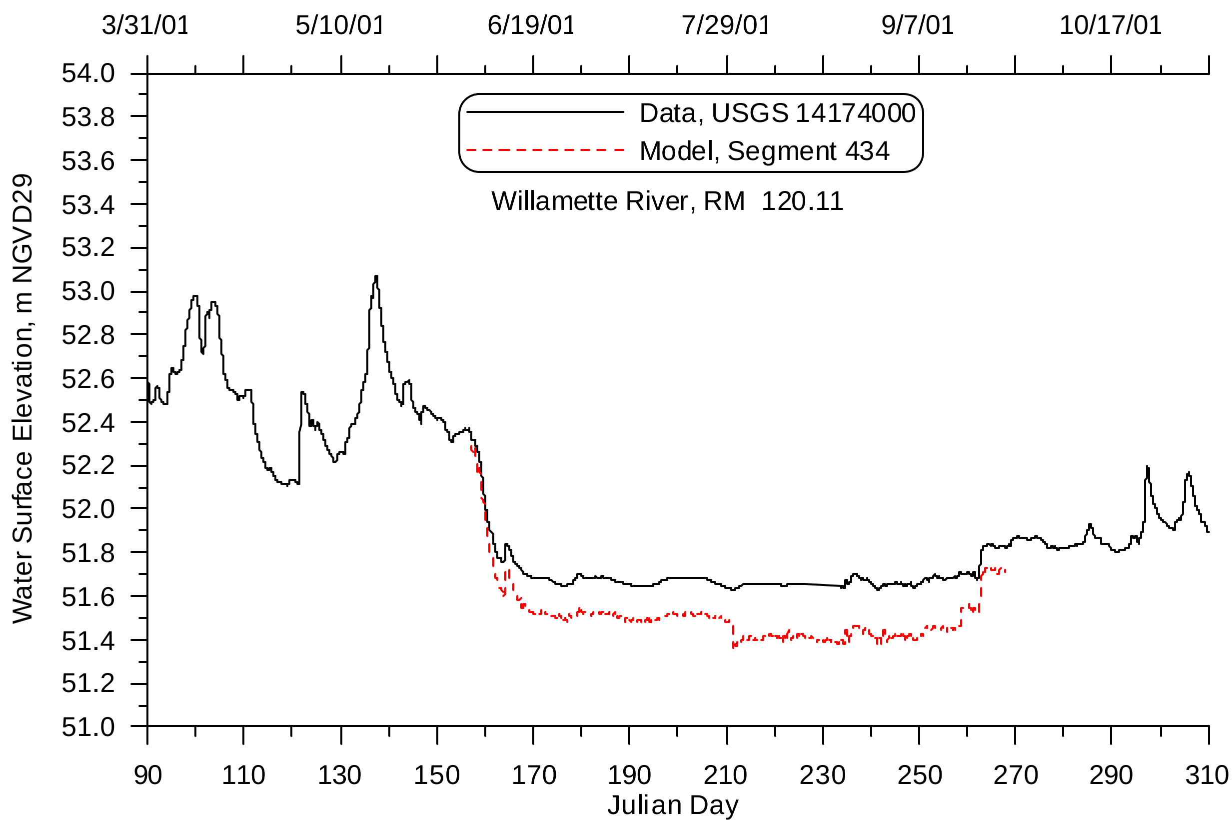

Figure 180: Willamette River at Albany model-data water level comparison, 2001

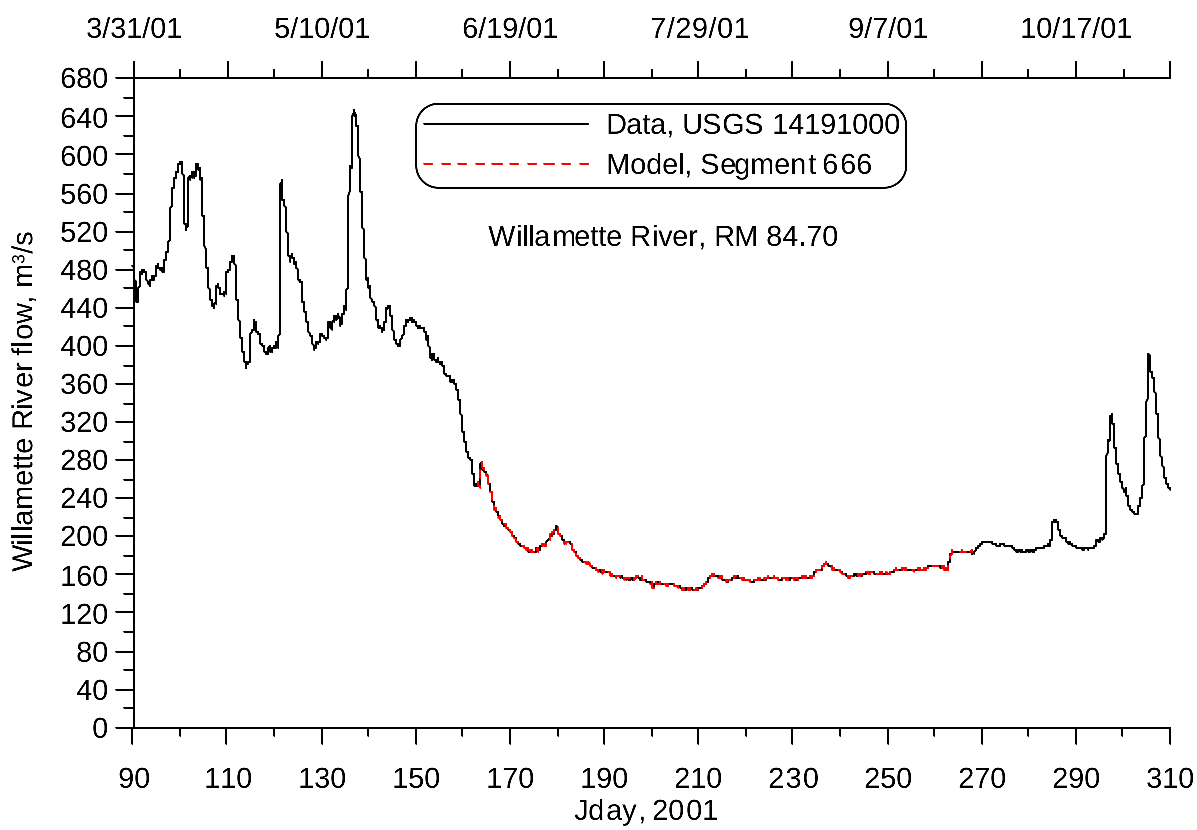

Figure 181: Willamette River at Salem model-data flow comparison, 2001 (gage is 900 m downstream)

Year 2002

Plots of 2002 model-data comparisons are shown for flow and water surface elevation at Eugene in Figure 182 and Figure 183; for flow and water surface elevation at Harrisburg in Figure 184 and Figure 185; for flow and water surface elevation at Corvallis in Figure 186 and Figure 187; for flow and water surface elevation at Albany in Figure 188 and Figure 189; and for flow at Salem in Figure 190.

Calibration statistics for the 2001 hydrodynamic stations are shown in Table 23. Errors in flow magnitude are around 1.0 m^3/s except at Salem which has an error of 1.6 m^3/s. This error is less than 1% of the flow. Errors in water surface elevation are 0.12 m or less.

Table 23: Upper Willamette River hydrodynamic calibration statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
ACOE EUGO3	182.45	19	5721	0.18	0.47	0.64
USGS 14166000	161.98	156	5760	-0.17	0.66	1.03
ACOE CORO3	132.32	352	11081	-0.06	0.37	0.61
USGS 14174000	120.11	434	5760	-0.10	0.37	0.55
USGS 14191000	84.70	665*	5760	-0.08	0.97	1.63
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
ACOE EUGO3	182.45	19	5721	0.01	0.02	0.03
USGS 14166000	161.98	156	5760	0.04	0.04	0.05
ACOE CORO3	132.32	352	11081	-0.01	0.01	0.01
USGS 14174000	120.11	434	5760	-0.12	0.12	0.12
USGS 14191000	84.70	665*	5760	Not appropriate comparison, 1 km downstream of model grid		

The model flow and water surface elevation at Albany (Figure 188 and Figure 189) exhibit more "noise" than the other stations. Attempts to alleviate the noise were not successful. Refinements to the water balance and alternative timings were attempted. The same magnitude of noise is seen at Salem, but the flow is much greater masking the noise.

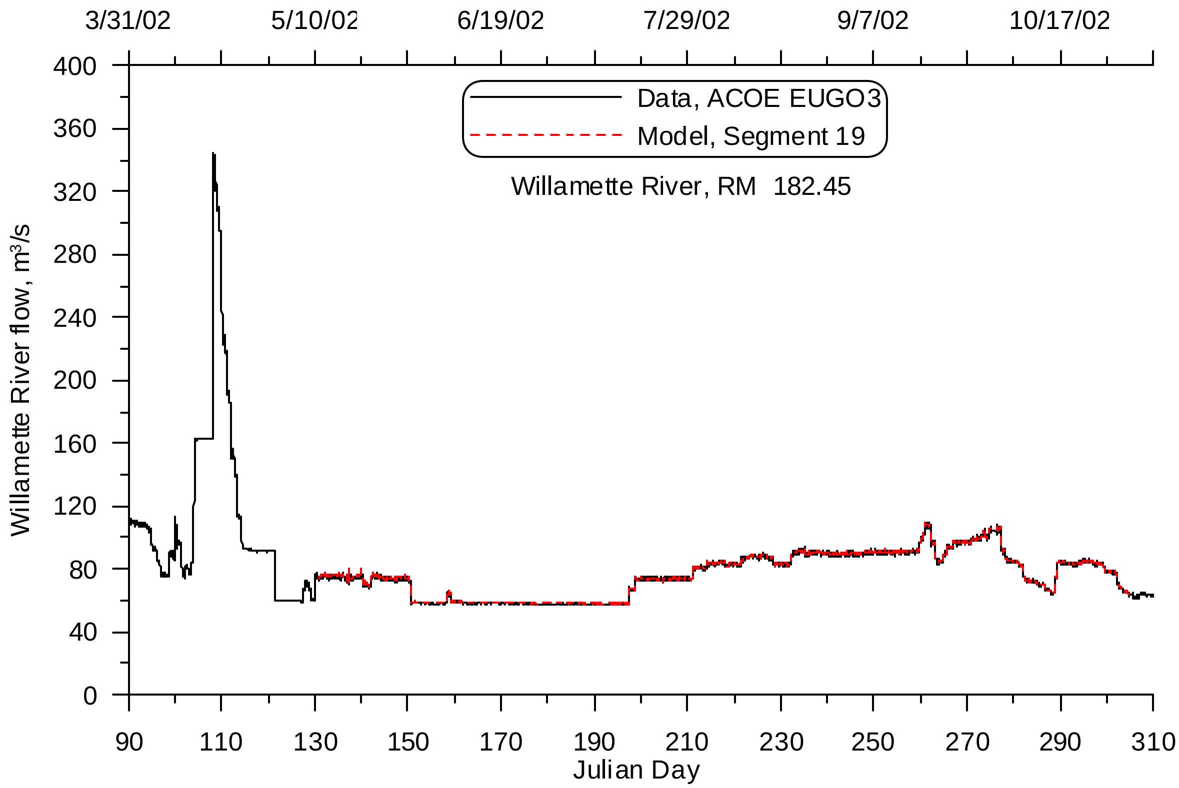

Figure 182: Willamette River at Eugene model-data flow comparison, 2002

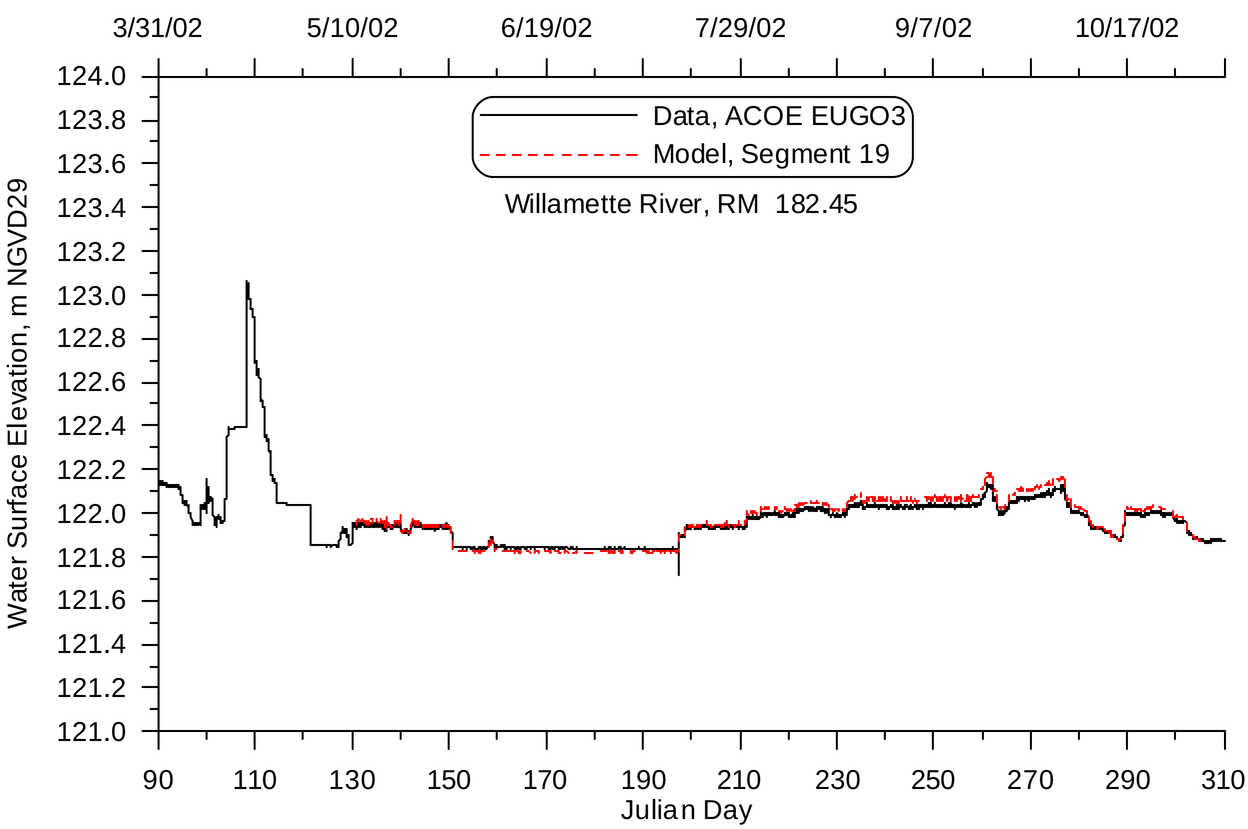

Figure 183: Willamette River at Eugene model-data water level comparison, 2002

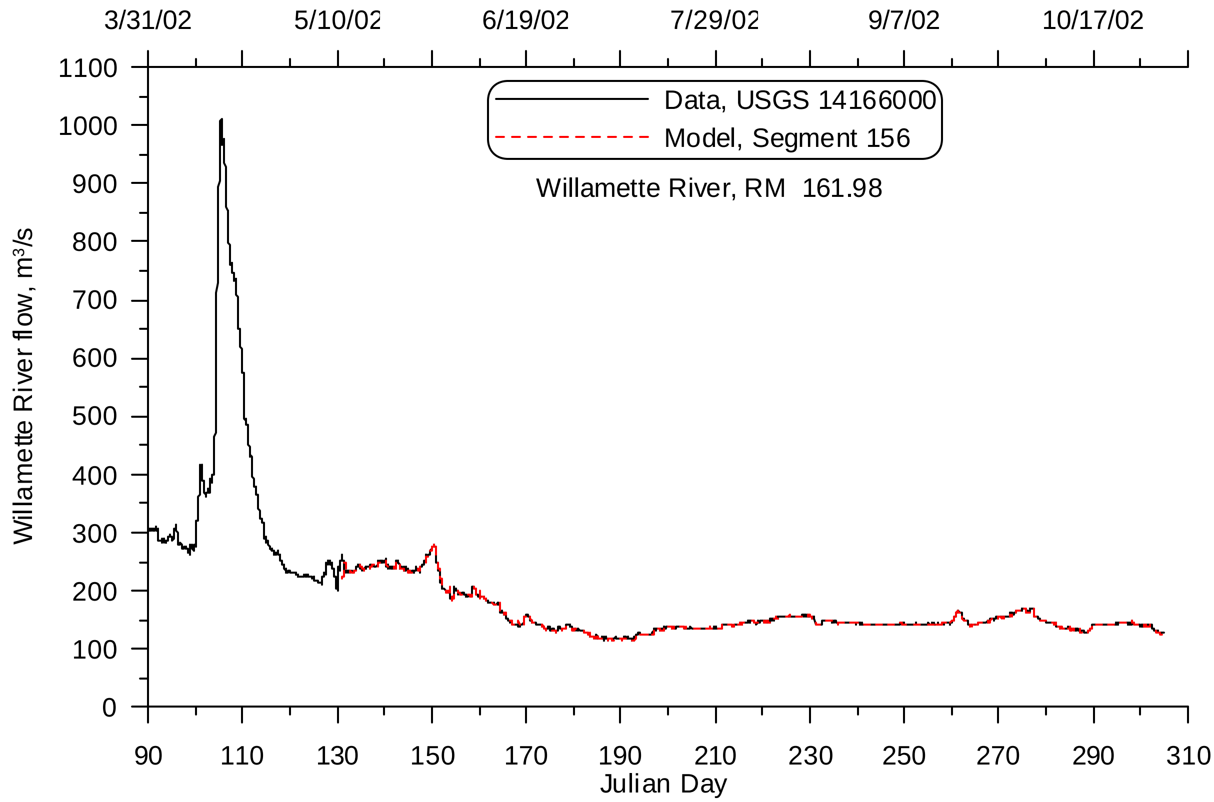

Figure 184: Willamette River at Harrisburg model-data flow comparison, 2002

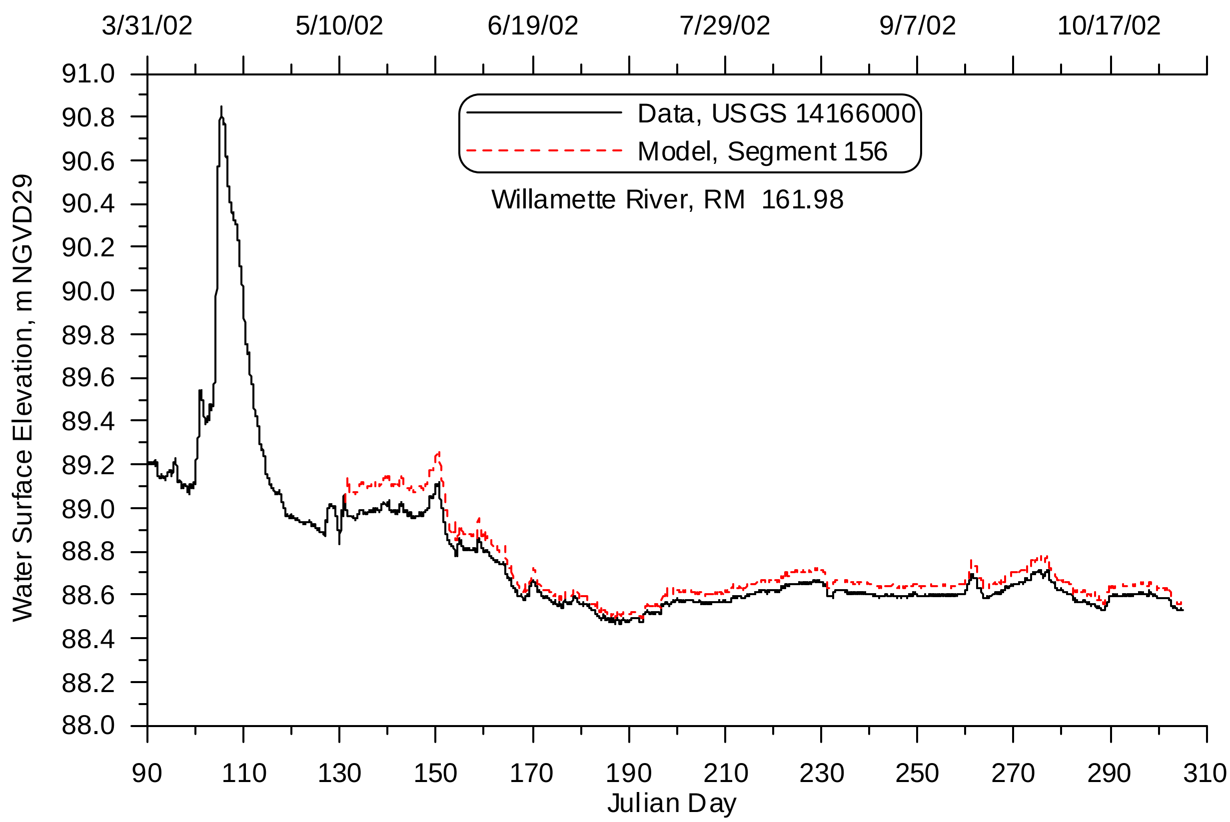

Figure 185: Willamette River at Harrisburg model-data water level comparison, 2002

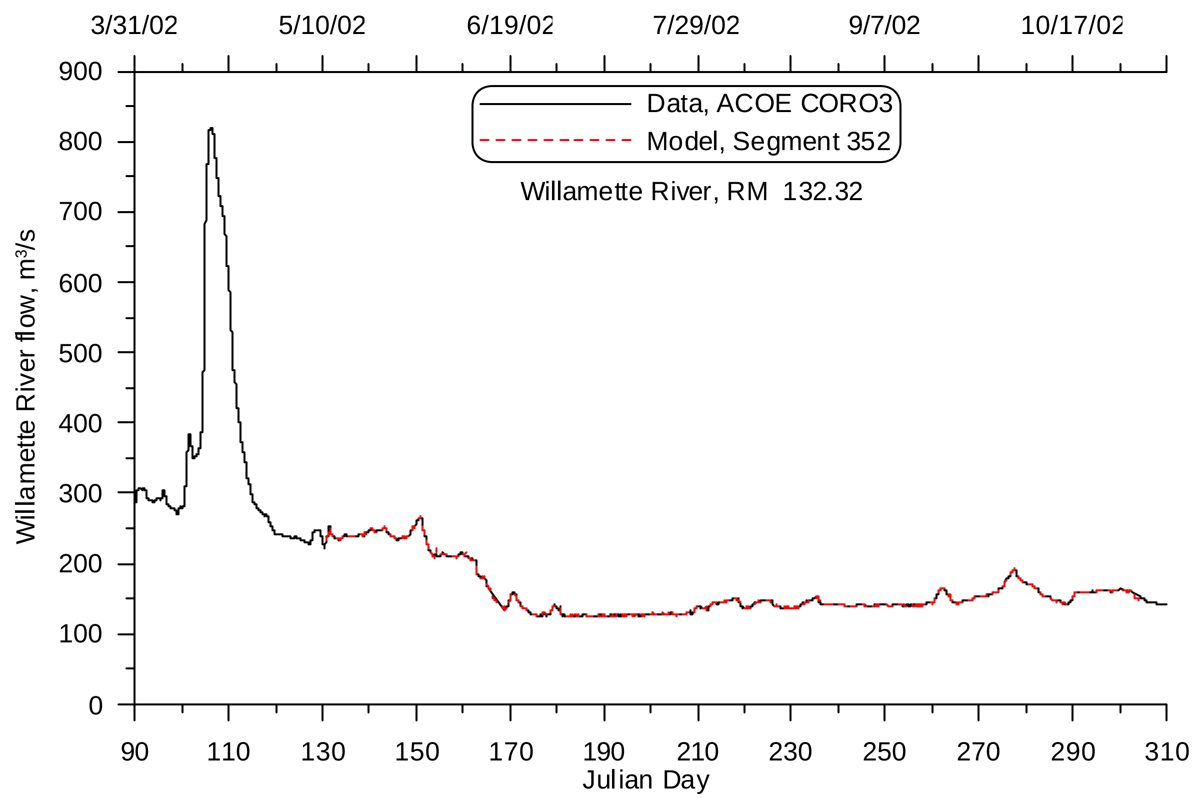

Figure 186: Willamette River at Corvallis model-data flow comparison, 2002

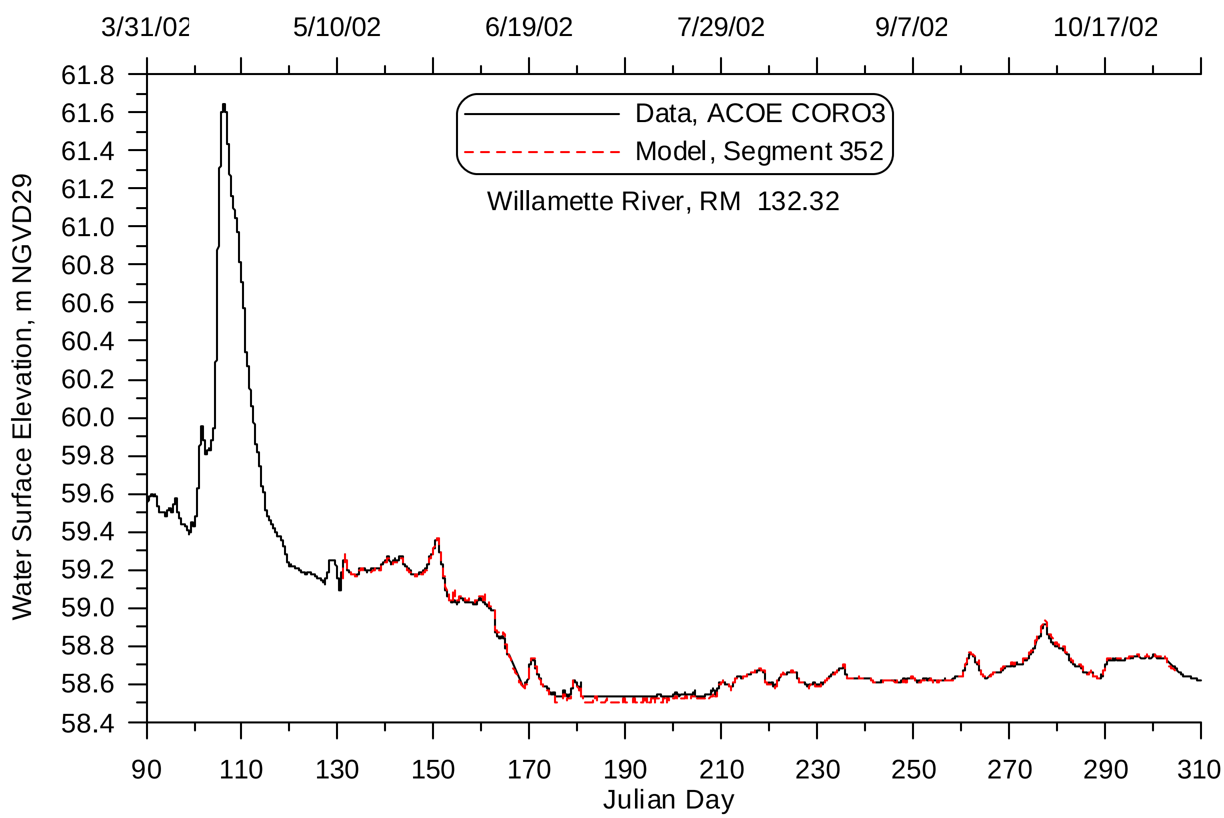

Figure 187: Willamette River at Corvallis model-data water level comparison, 2002

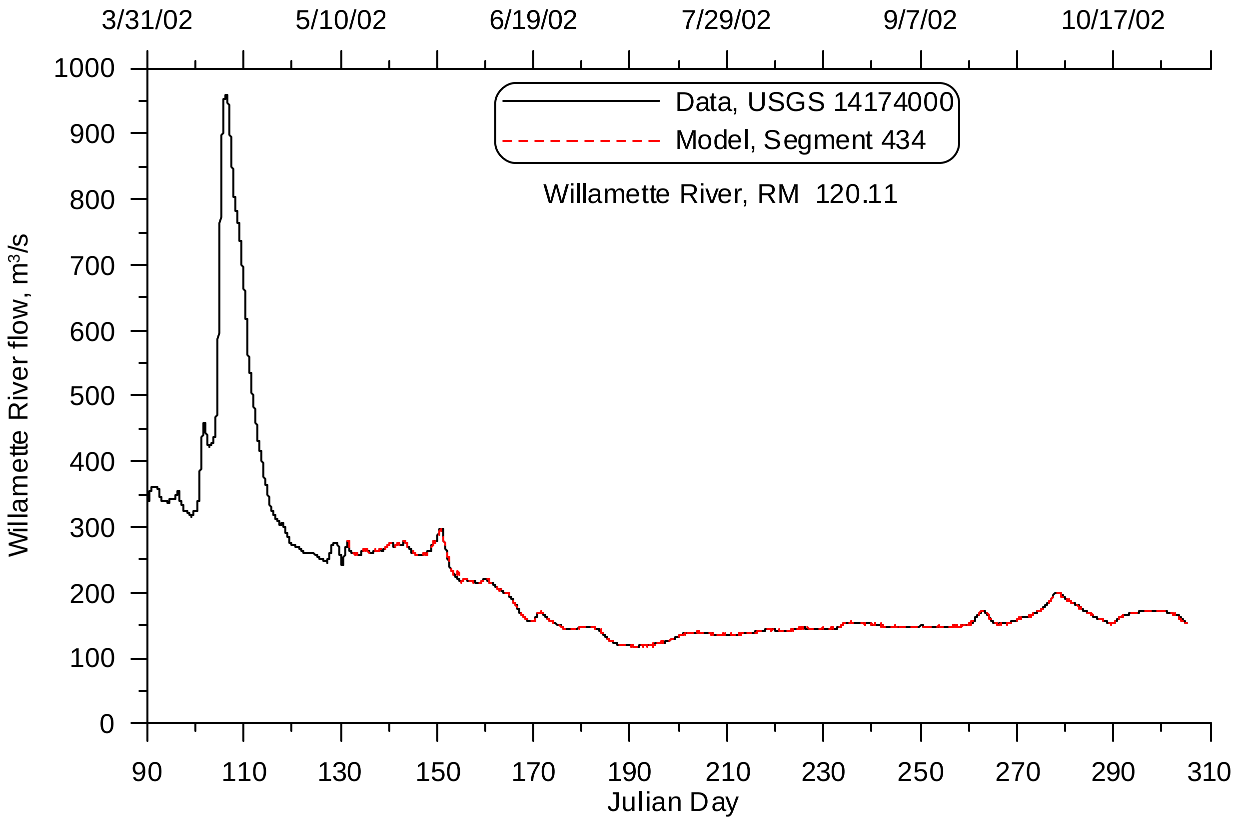

Figure 188: Willamette River at Albany model-data flow comparison, 2002

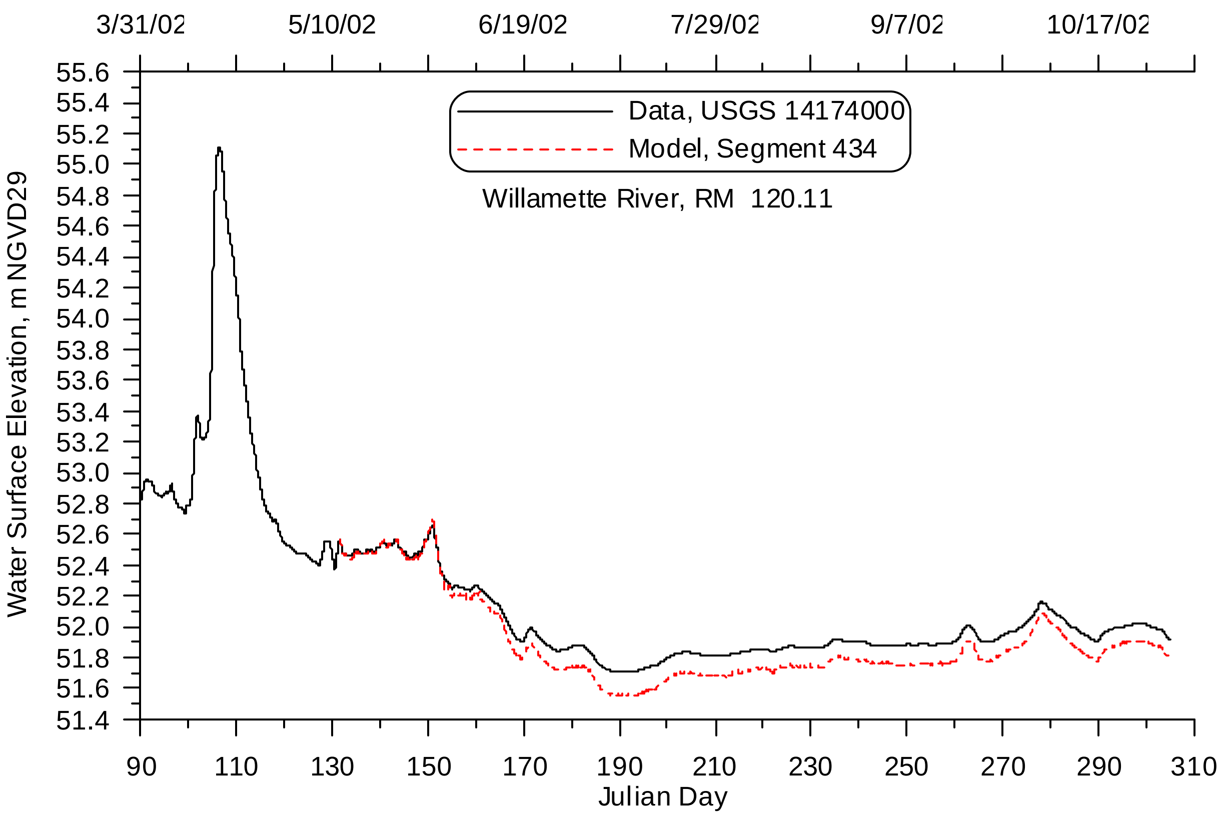

Figure 189: Willamette River at Albany model-data water level comparison, 2002

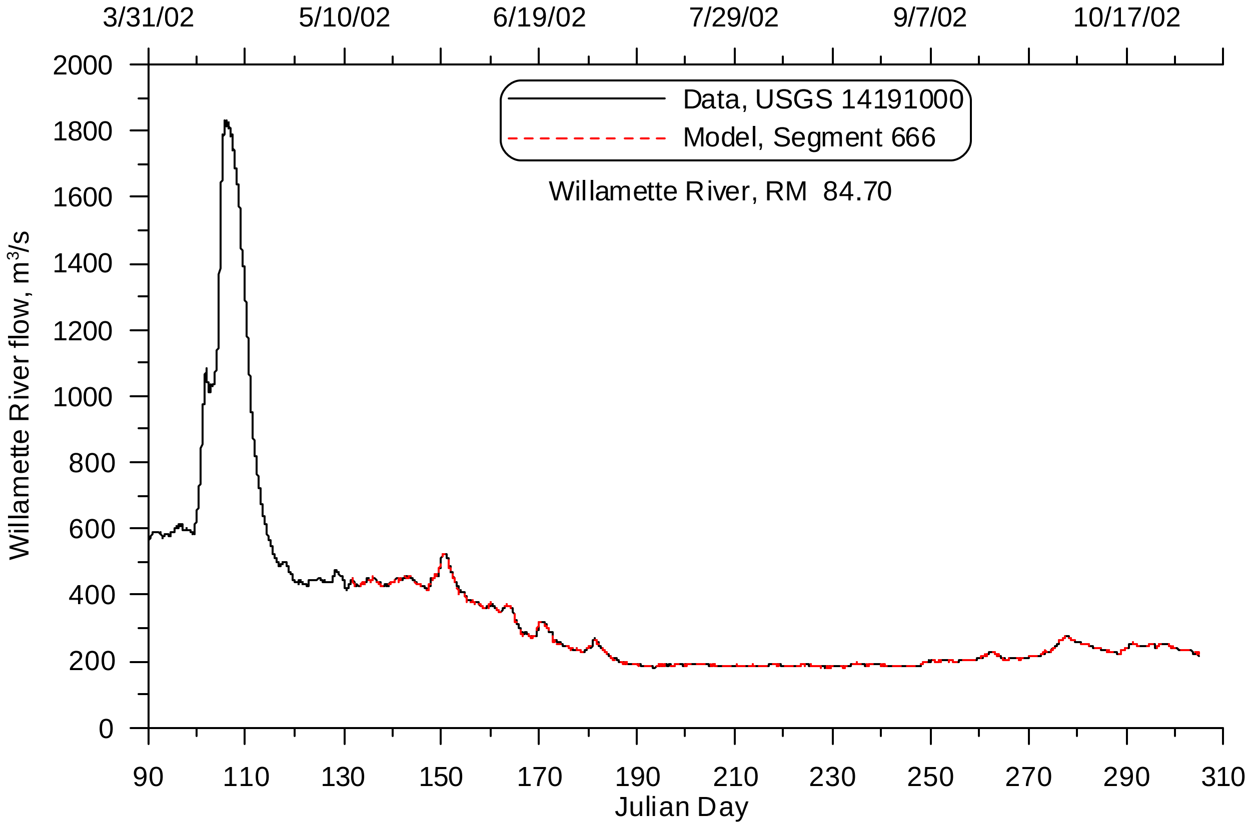

Figure 190: Willamette River at Salem model-data flow comparison, 2002 (gage is 900 m downstream).

Water Balance flows

At each point which had continuous flow data, a water balance was made using the frequency of the data. The water balance flows were added to the existing distributed flows. Distributed flows are allocated by branches, and within each branch, flow is applied to each segment proportional to the current segment active water surface area.

The 2001 and 2002 calibration flows over each calibration reach are qualitatively and quantitatively similar. The dominant mechanism the calibration flows account for in the model are groundwater exchange and ungaged surface inflows with the river.

<u>Year 2001</u>

The USACOE gage at Eugene was used as the upstream flow boundary condition. In addition to the time lag, some small refinements to the flow were made. The calibration flow is shown in Figure 191, and was applied to branch 1.

The calibration flows between the gages at Eugene and Harrisburg result in roughly a 10 to 15 m^3/s withdrawal, on average. The calibration flows were apportioned to branches 2, 3, and 4 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 192.

The calibration flows between the gages at Harrisburg and Albany result in inflows ranging from 0 to 20 m^3/s in the spring period, and starting in roughly August, the typical flow is a small water loss ranging from 1 to 4 m^3/s. The calibration flows were apportioned to branches 5, 6, 7, and 8 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 193.

The calibration flows between the gages at Albany and Salem result in a water flux generally ranging from -10 to 30 m^3/s, with a peak loss rate approaching 30 m3/s The calibration flows were apportioned to branches 9, 10, 11, 12, and 13 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 194.

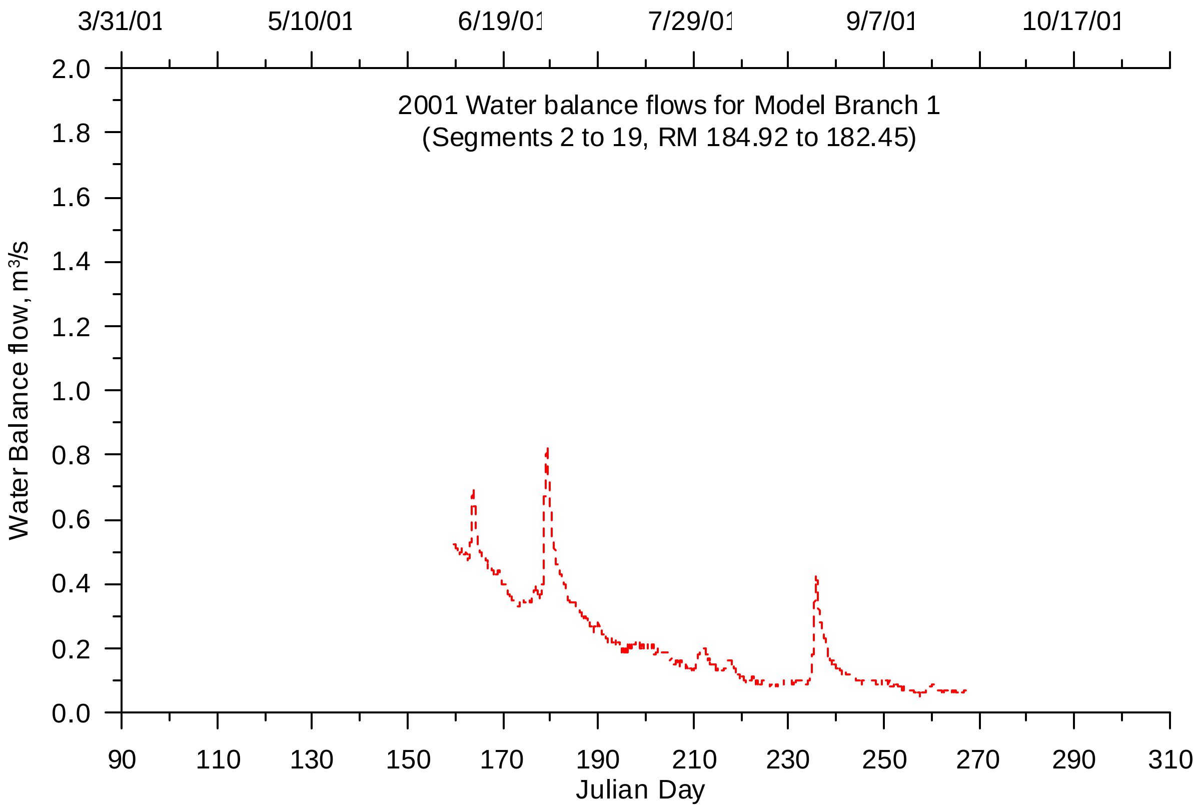

Figure 191: Upper Willamette River water balance flows for model Branch 1, 2001

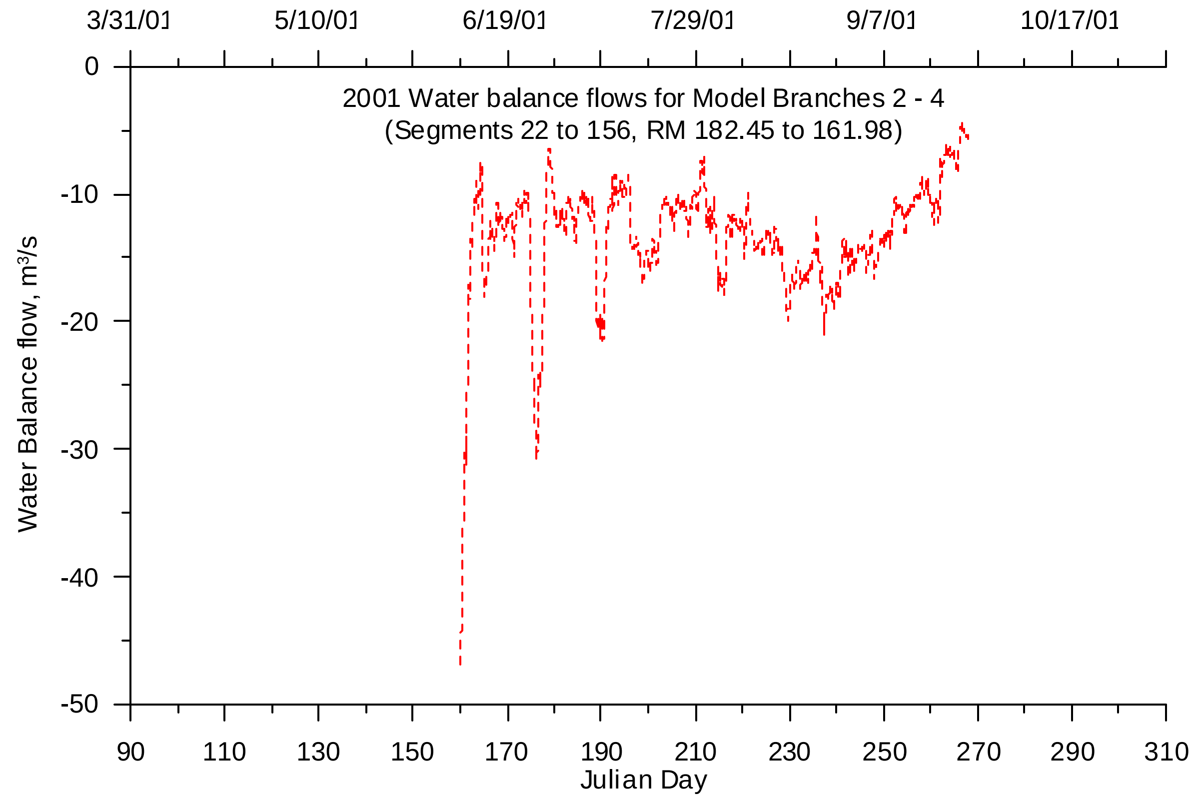

Figure 192: Upper Willamette River water balance flows for model Branches 2 to 4, 2001

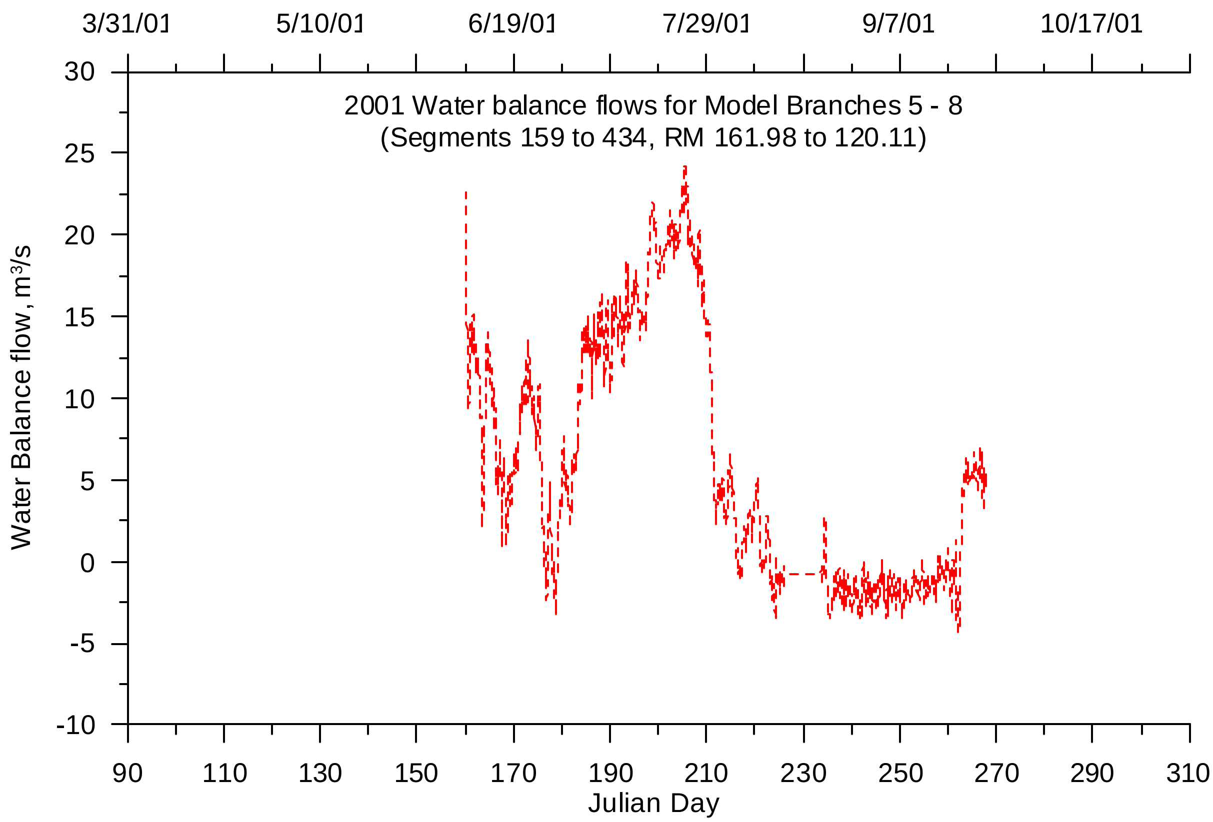

Figure 193: Upper Willamette River water balance flows for model Branches 5 to 8, 2001

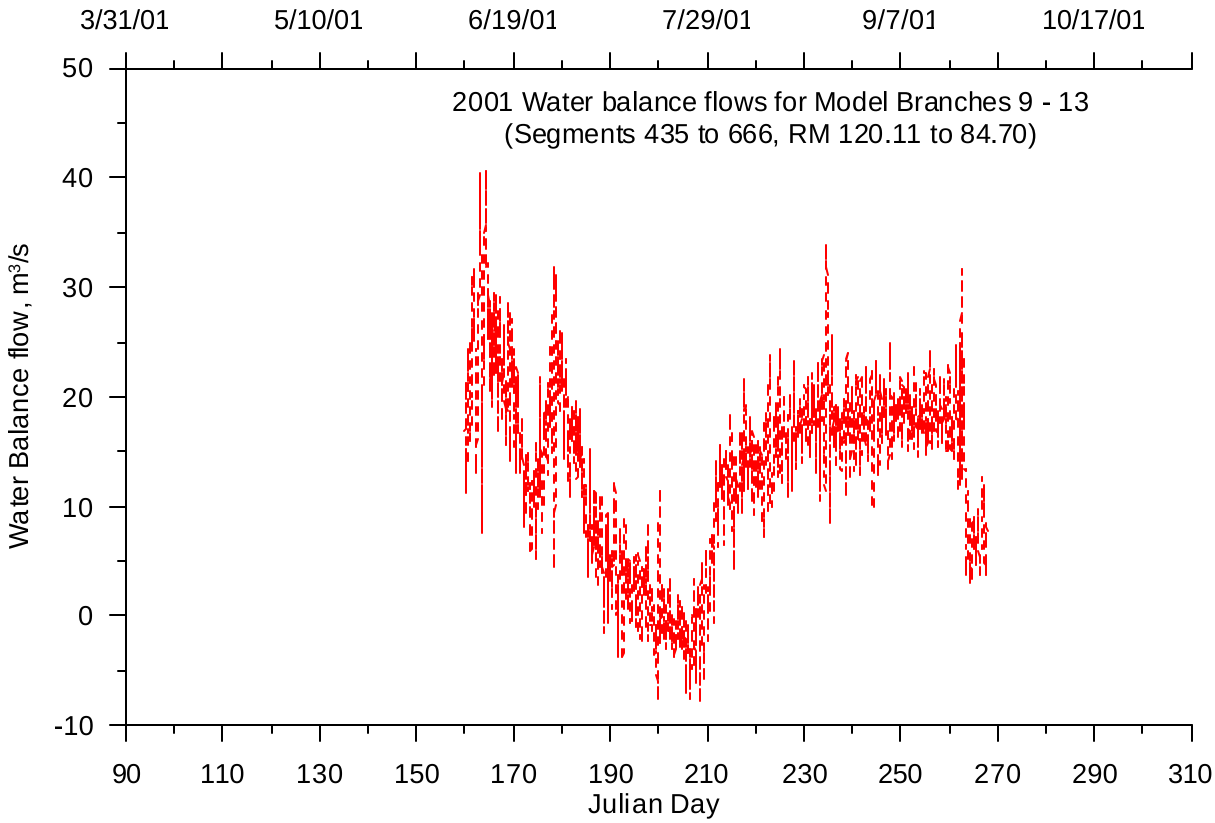

Figure 194: Upper Willamette River water balance flows for model Branches 9 to 13, 2001

Year 2002

The USACOE gage at Eugene was used as the upstream flow boundary condition. In addition to the time lag, some small refinements to the flow were made. The calibration flow is shown in Figure 195, and was applied to branch 1.

The calibration flows between the gages at Eugene and Harrisburg result in roughly a 10 to 20 m^3/s withdrawal, on average. The calibration flows were apportioned to branches 2, 3, and 4 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 196.

For the 2002 model year, an additional calibration site at Corvallis was available. The calibration flows between the gages at Harrisburg and Corvallis result in inflows ranging from 0 to 20 m^3/s in the spring period, and starting in roughly August, the typical flow is a small water loss ranging from 1 to 4 m^3/s. The calibration flows were apportioned to branches 5, 6, and 7 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 197.

The calibration flows between the gages at Corvallis and Albany result in a water flux ranging from –1 to 5 m^3/s. The calibration flows were apportioned to branch 8, and added to any existing distributed flows. The calibration flow is shown in Figure 198.

The calibration flows between the gages at Albany and Salem result in a water flux ranging from –5 to 30 m^3/s. The calibration flows were apportioned to branches 9, 10, 11, 12, and 13 on the basis of length, and added to any existing distributed flows. The calibration flow is shown in Figure 199.

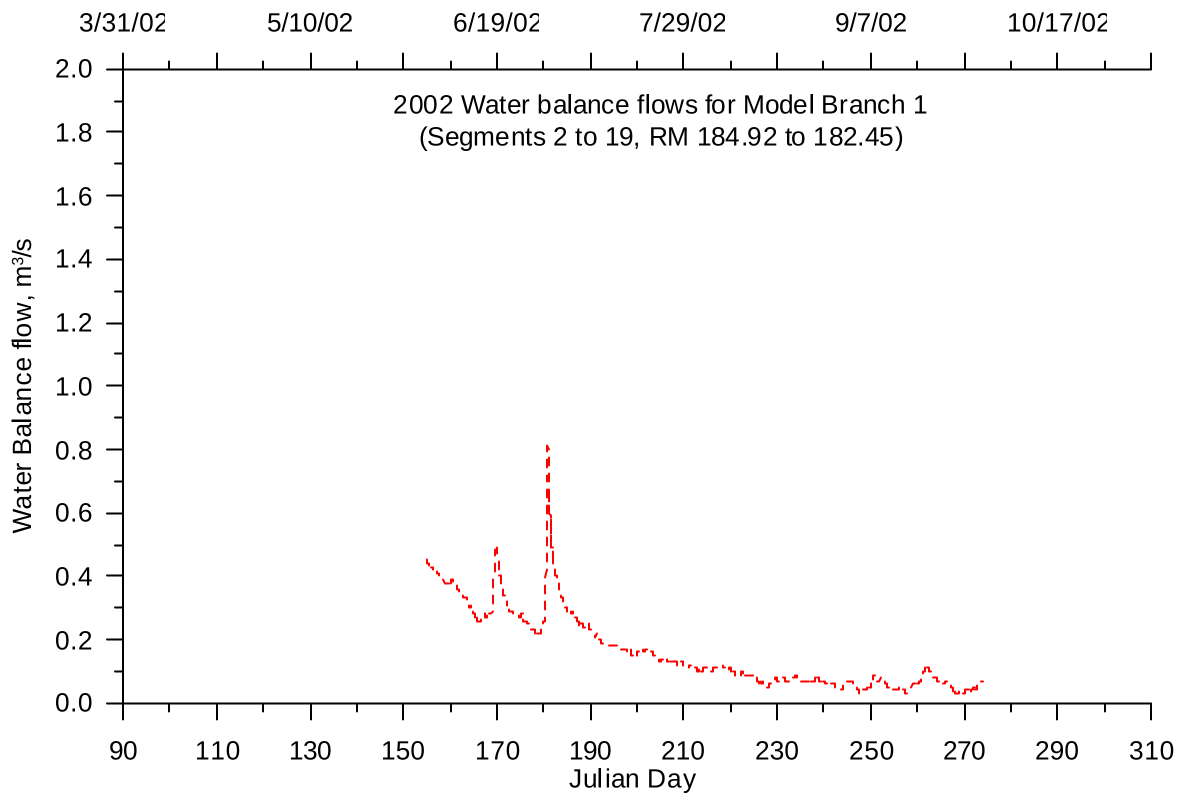

Figure 195: Upper Willamette River water balance flows for model Branch 1, 2002

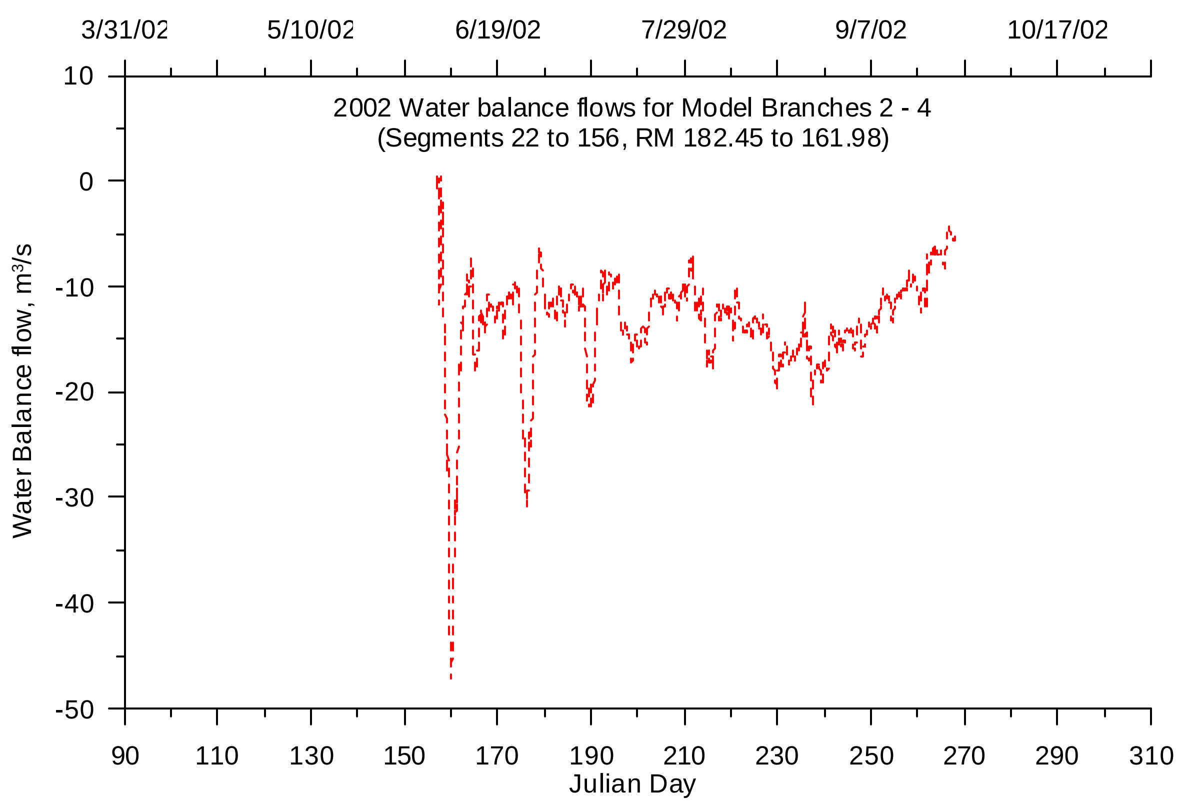

Figure 196: Upper Willamette River water balance flows for model Branches 2 to 4, 2002

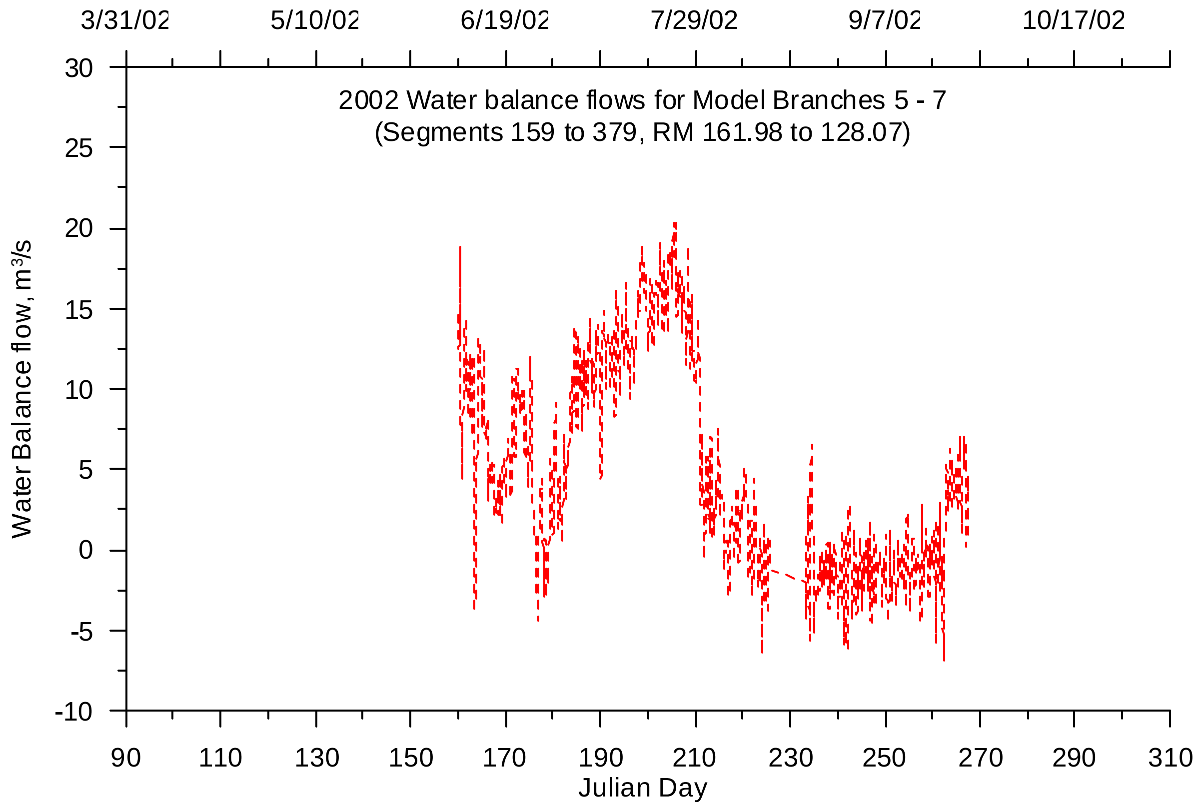

Figure 197: Upper Willamette River water balance flows for model Branches 5 to 7, 2002

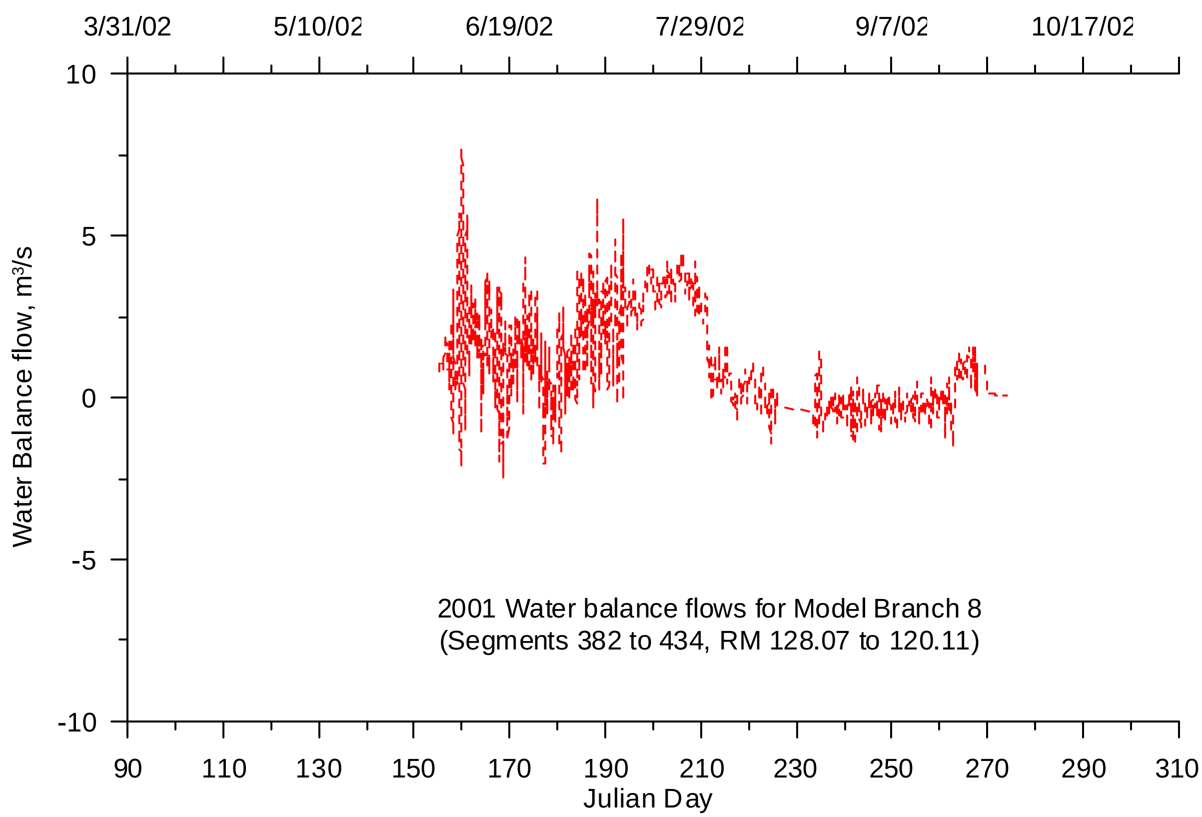

Figure 198: Upper Willamette River water balance flows for model Branch 8, 2002

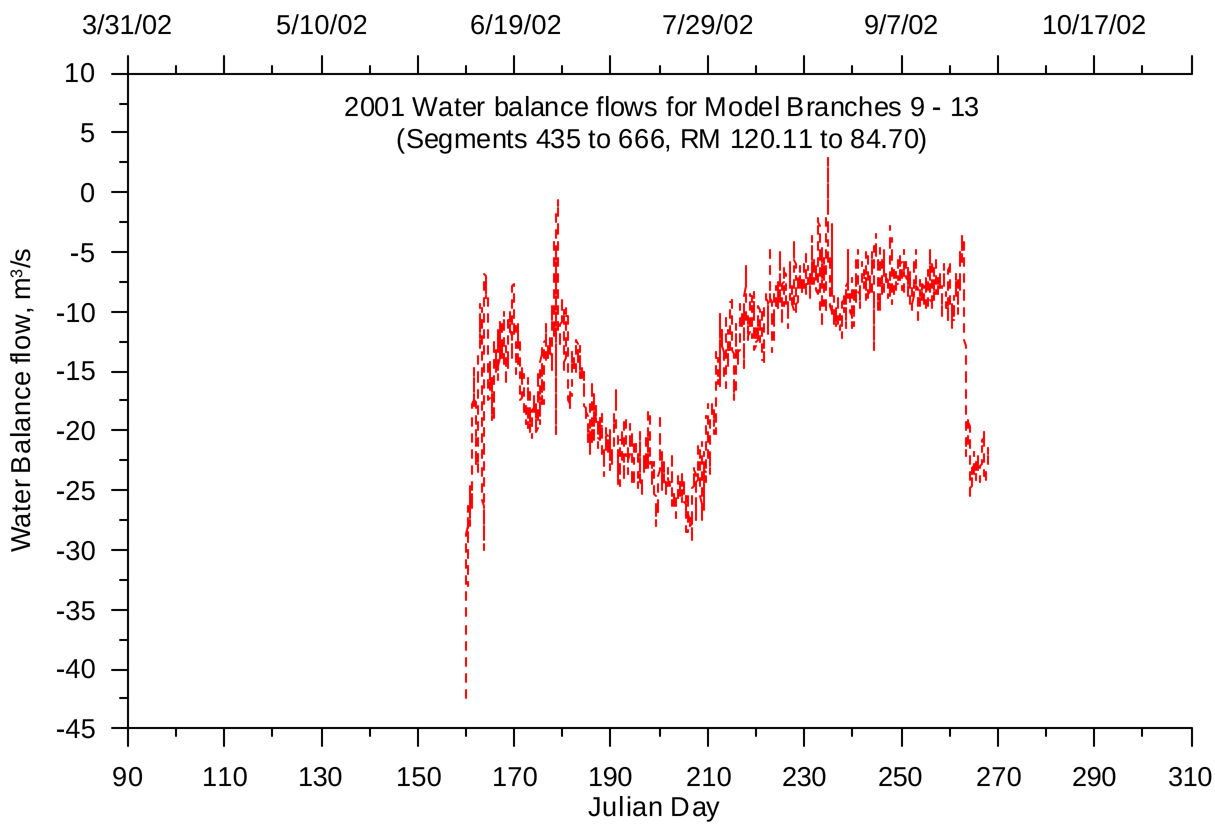

Figure 199: Upper Willamette River water balance flows for model Branches 9 to 13, 2002

Channel Widths

Wetted channel width data was provided by the Oregon Department of Environmental Quality. The width data was based on Digital Ortho-Quad map photographs at different dates and flows. Using the dates of the photographs, discharges appropriate to the wetted width data over the model area were generated. The model simulation dates used to make the model-data comparisons and the associated model segments are shown in Table 24.

Table 24: Wetted width Digital Ortho-Quadrangle image model-data date and river discharge comparisons.

Station	Station ID	DOQ Image dates	Actual Discharge, m^3/s	Model Discharge, m^3/s	Model Date	Model Segments
Eugene	USACOE EUGO3	06/19/1994 06/27/1997	40-70	59	06/24/2002	2-70
Harrisburg	USGS 14166000	06/19/1994 06/27/1997	133-170	141	09/02/2002	71-279
Albany	USGS 14174000	05/23/1994 06/19/1999	160-260	220	06/09/2002	280-508
Salem	USGS 14191000	05/23/1994 06/19/1995	315-450	446	05/20/2002	509-666

A plot of model-data wetted widths is shown as Figure 200. Model widths are sensitive to the magnitude of the flow. The model under predicts the channel width upstream of the McKenzie River confluence. The narrow width was used to reduce the model diurnal temperature variation at model segment 53, LASAR 28723. Under low flows, the model is generally 2 or 3 layers thick. The surface width presents a considerable constraint to the calibration of the temperature diel fluctuation.

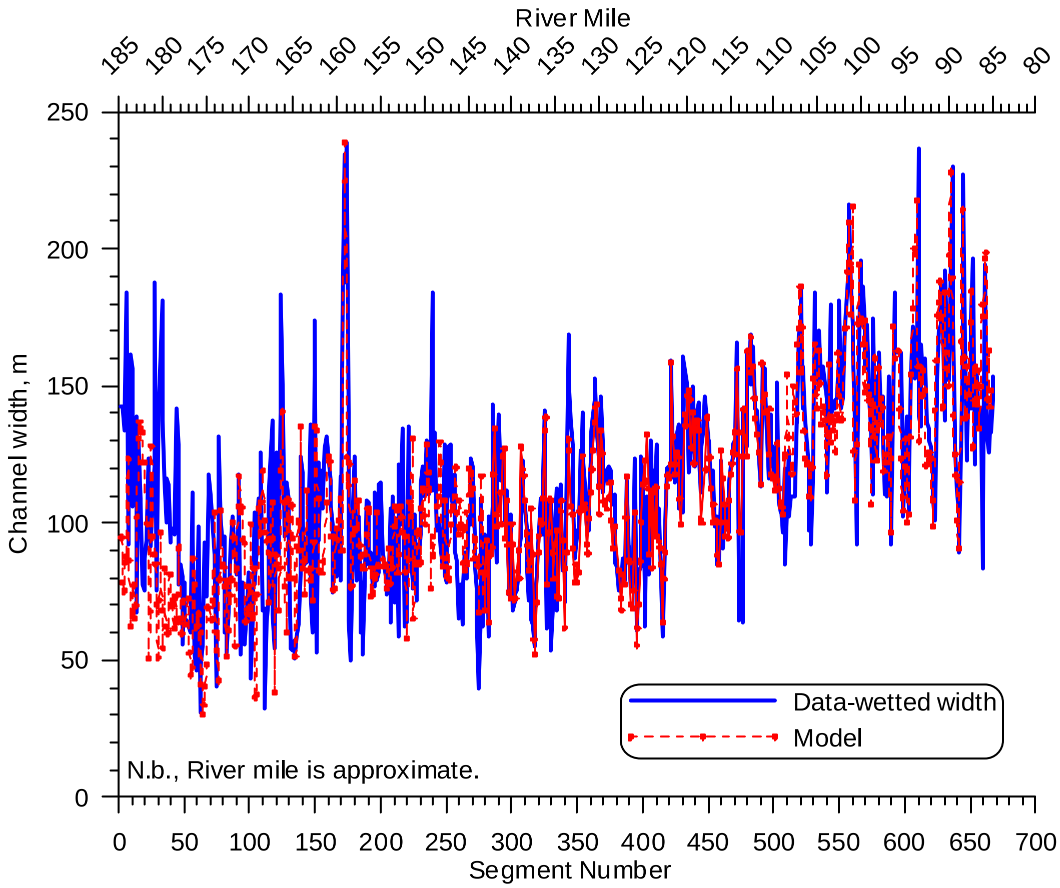

Figure 200: Model-data wetted width comparison.

Time of Travel/Dye Studies

Two types of dye study data are available for the Upper Willamette River model. During the 1960's the USGS conducted extensive travel rate vs. discharge studies (Harris, 1968; Appendix B, Annear et al, 2004a). More recently, the USGS and the EPA have conducted single flow time of travel and longitudinal dispersion dye studies over selected reaches.

1968 Harris Study: Travel Rates

The Harris Study examined time of travel for varied flows over the length of the model area. Table 25 shows the reaches examined in the study and the model segments associated with the ends of the reaches. Where possible, geographic features were used to select the appropriate model segment. The reported Willamette River mile are those generated in this report and differ slightly from the river mile reported in the Harris Study. It is uncertain how much the channel morphology and travel rates have changed between the studies, which were conducted in 1962-63, and the model calibration period, roughly 30 years; however, the data should provide a strong starting point for calibrating flow rates.

Model travel rates under 5 flows are compared to the Harris Study flow rates in Figure 201, Figure 202, and Figure 203. The highest model flow in reach 9, Figure 202, shows disagreement with the data and with the other model results in reach 9. This could be a model instability. The flow is well above the model simulation period flow.

Table 25: Upper Willamette River 1968 time of travel reaches, (Harris, 1968)

Reach	Upstream End	Up-stream RM	Model Segment	Downstream End	Down-stream RM	Model Segment
4	Ferry Street Bridge, Eugene	182.3	16	McKenzie River	174.8	71
5	McKenzie River	174.8	71	Harrisburg Bridge	161.2	160
6	Harrisburg bridge	161.2	160	Irish Bend	151.3	226
7	Irish Bend	151.3	226	Long Tom River	145.8	263
8	Long Tom River	145.8	263	Peoria	141.5	291
9	Peoria	141.5	291	Corvallis filtration plane	133.8	340
10	Corvallis filtration plane	133.8	340	Camp Adair water intake	122.0	418
11	Camp Adair water intake	122.0	418	Albany bridge	119.4	437
12	Albany bridge	119.4	437	Santiam River	108.0	515
13	Santiam River	108.0	515	Buena Vista Ferry	106.4	525
14	Buena Vista Ferry	106.4	525	Independence bridge	96.0	596
15	Independence bridge	96.0	596	Rickreall Creek	88.1	647

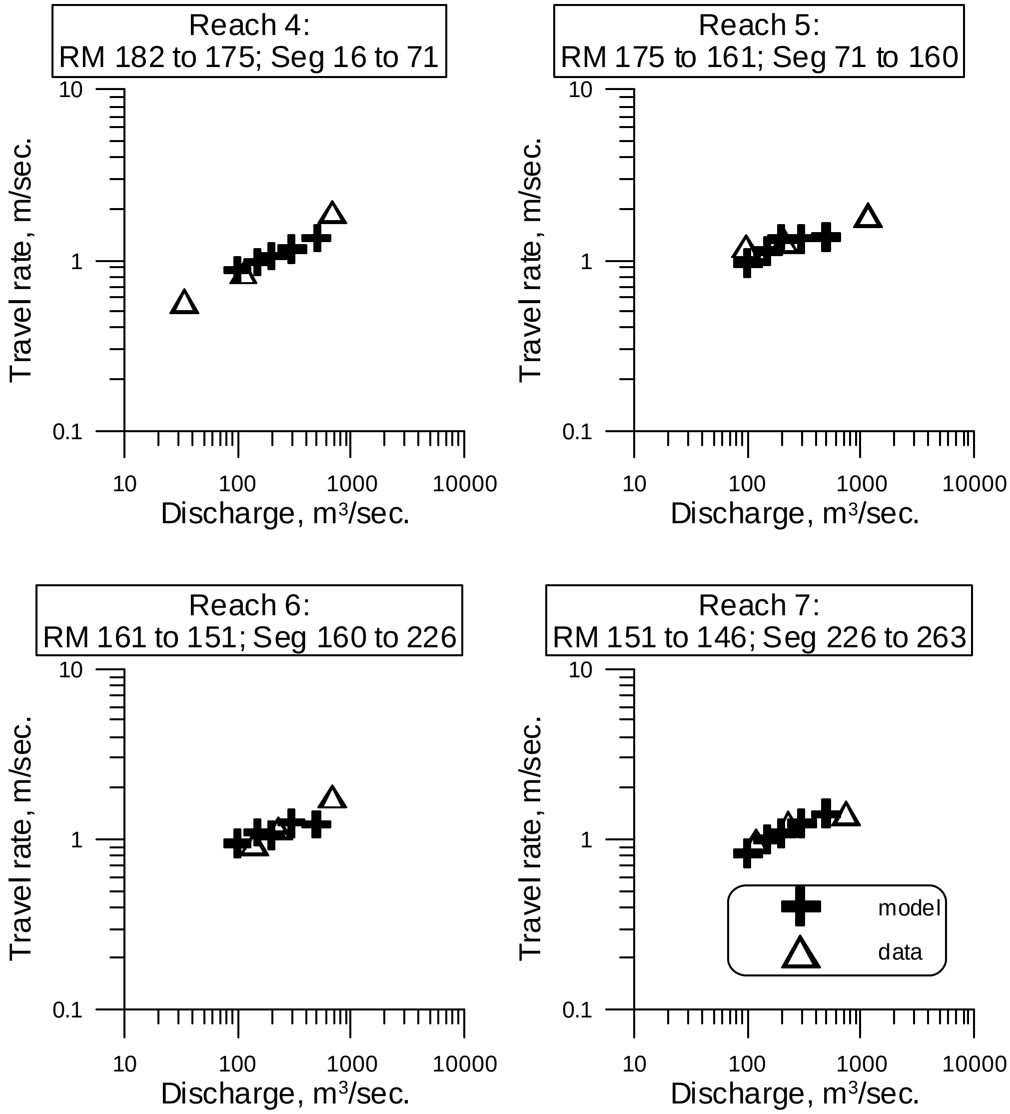

Figure 201: Model-data comparisons of Harris Study travel rates over RM 182 to 146.

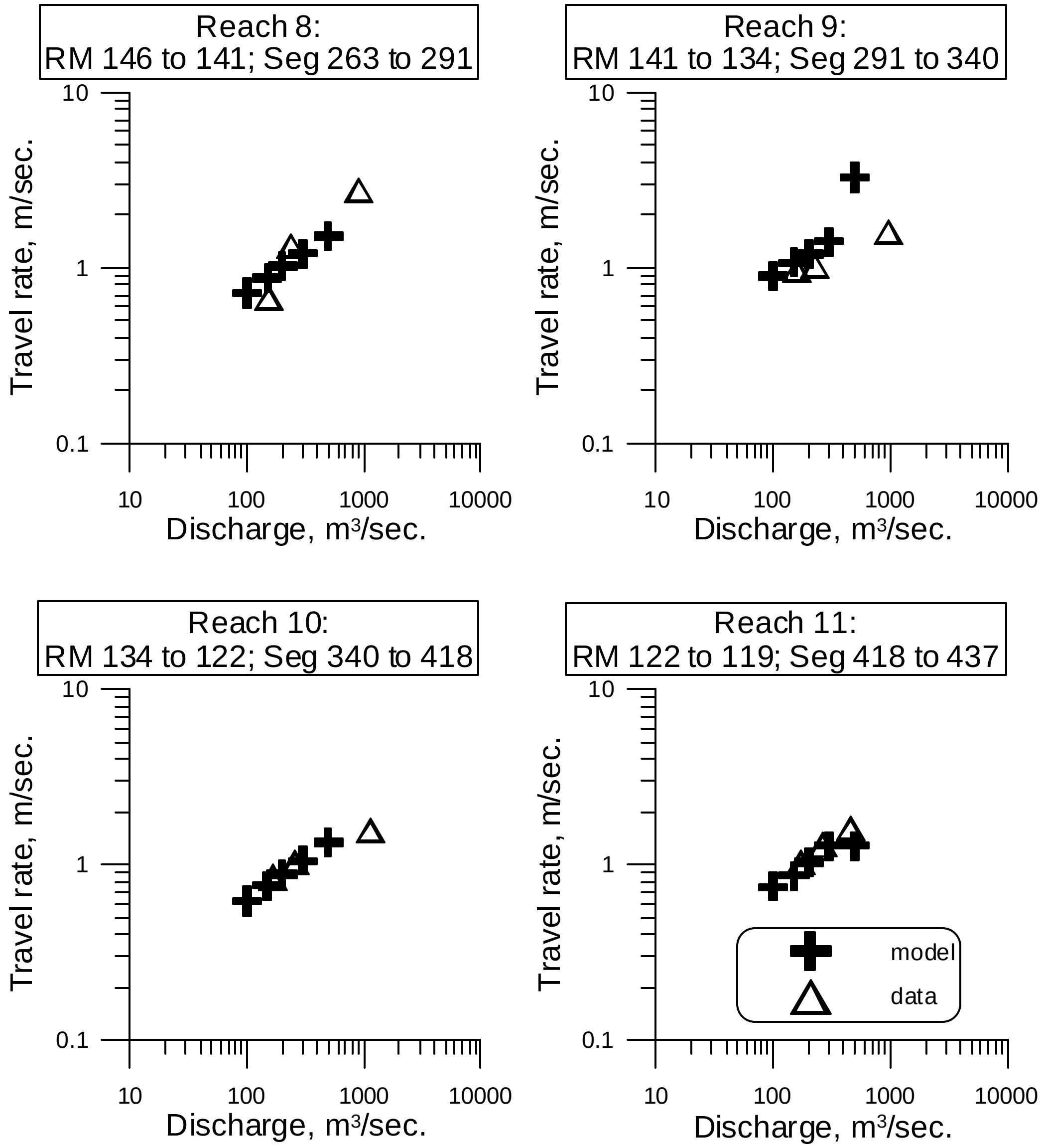

Figure 202: Model-data comparisons of Harris Study travel rates over RM 146 to 119

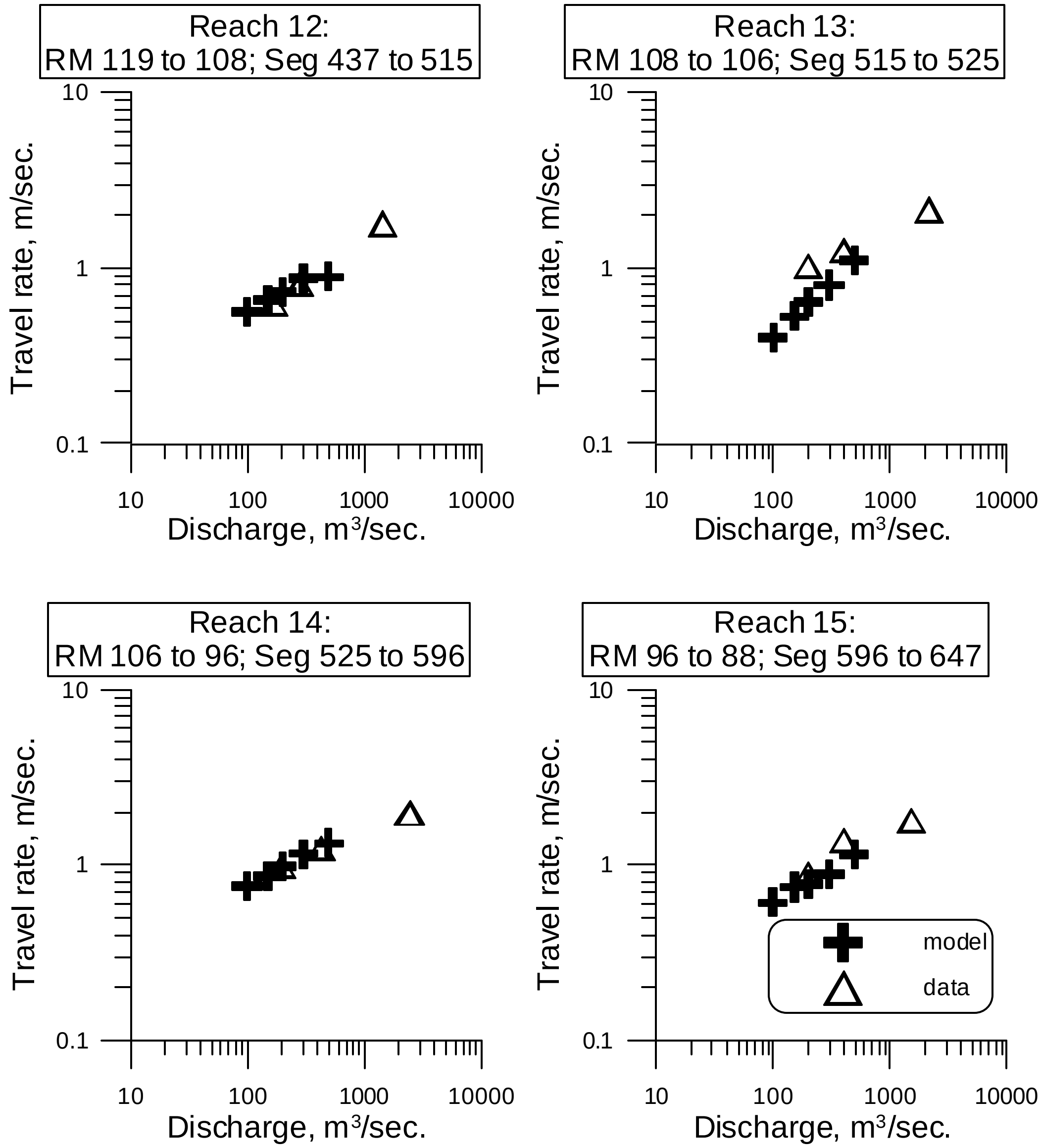

Figure 203: Model-data comparisons of Harris Study travel rates over RM 119 to 88

Dye Studies

Three recent sets of time of travel dye studies over seven reaches were simulated. The model segments and river miles are shown in Table 26. The river miles reported are those used in this report and differ from the river miles reported in the primary sources. Geographic features were used to select the model segments of the dye studies, where possible. In cases where the flow and water surface elevation data, wetted width data, dye study data, and temperature data could not be reconciled, flow, water surface elevation, and temperature calibration was given a stronger priority than dye study calibration.

Table 26: Upper Willamette River dye study locations and model segments.

Study	Study Date	Dye Volume, ml	Injection Model Segment, (RM)	1st Observation Model Segment, (RM)	2nd Observation Model Segment, (RM)	3rd Observation Model Segment, (RM)	4th Observation Model Segment, (RM)
1992 USGS	06/09/1992	1000	228 (151.0)	253 (147.4)	269 (144.9)	292 (141.3)	311 (138.4)
1992 USGS	06/10/1992	1400	160 (161.2)	190 (156.6)	208 (154.1)	228 (151.0)	292 (141.3)
1998 EPA	07/02/1998	600	100 (170.3)	104 (169.6)	111 (168.6)	121 (167.0)	---
1998 EPA	06/25/1998	820	121 (167.0)	134 (165.0)	155 (161.7)	172 (159.4)	---
1998 EPA	06/29/1998	1000	172 (159.4)	179 (158.3)	197 (155.5)	209 (153.9)	---
2002 USGS	06/12/2002	2800	288 (141.9)	316 (137.6)	335 (134.6)	352 (132.0)	377 (128.1)
2002 USGS	06/11/2002	2400	416 (122.3)	436 (119.5)	464 (115.5)	489 (111.6)	508 (108.6)

For each simulated dye injection, appropriate steady-state flows were used. No groundwater exchange, tributary or distributed tributary flows were used over any study reach. Model first-order tracer decay (CG1DK) and longitudinal dispersion (DX) where adjusted on a per segment basis. The mean dispersion value, Table 27, over each water body was applied to the general model. The values of dispersion and decay are shown in Figure 204 and Figure 205, respectively. The general model temperature results were not sensitive to the values of the longitudinal dispersion used. Increasing DX from 1 to 100 could mitigate the peak daily temperature by 0.25 °C at some points.

Table 27: Upper Willamette River dye study longitudinal dispersion values for the model.

Model Water body	**Average Dispersion (DX), m^2/sec.**
1	50
2	45
3	65
4	23
5	1
6	37
7	50
8	50
9	50

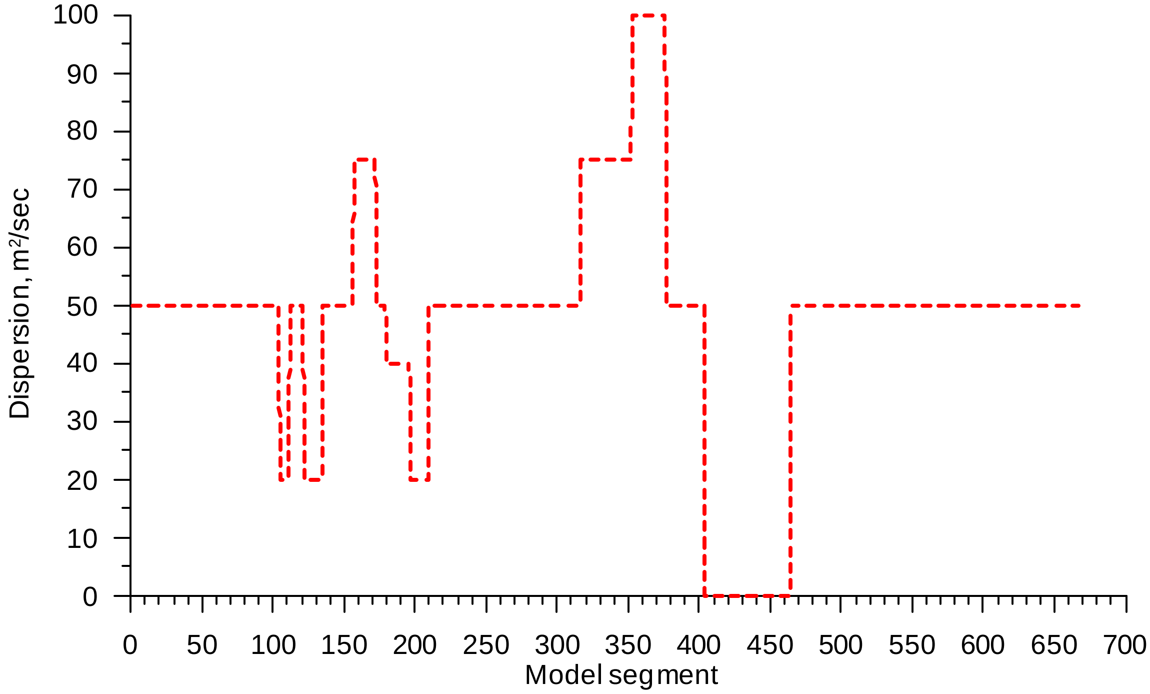

Figure 204: Model dye study dispersion values.

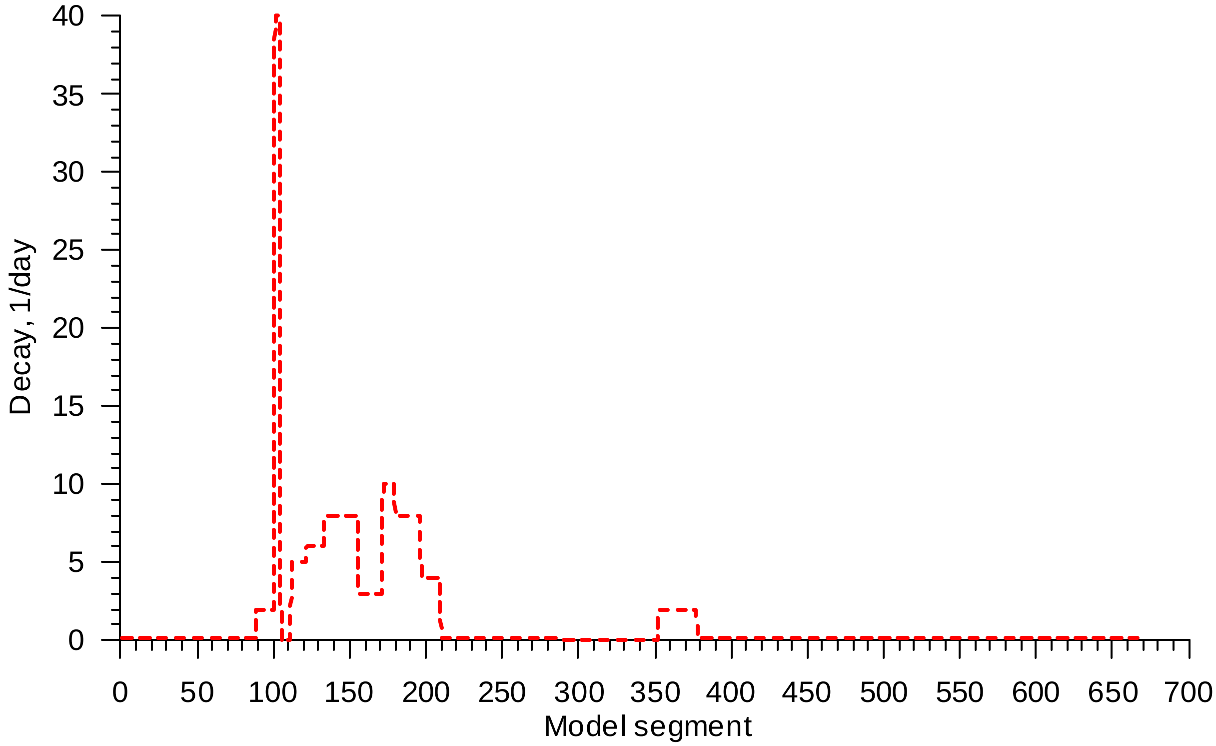

Figure 205: Model dye study first-order decay values.

1992 USGS Willamette River Dye Studies

Two 1992 USGS dye study reaches were simulated. The study area, from RM 161 to RM 138, is shown in Figure 206. The model-data comparisons are shown in Figure 207, and Figure 208. Where the 1992 dye studies overlapped with the 1998 dye studies, roughly RM 161 to 154, if both studies could not be matched simultaneously, the 1998 dye study was given calibration preference. The June 10, 1992, model simulation shown in Figure 208 utilized no tracer decay, unlike the 1998 studies that required decay.

Travel rates for the sub-reaches in the June 9 study were not entirely met. Increasing the travel rate disrupted the timing of the temperature calibration at LASAR 26722 and 10253, RM 142 and 135, respectively.

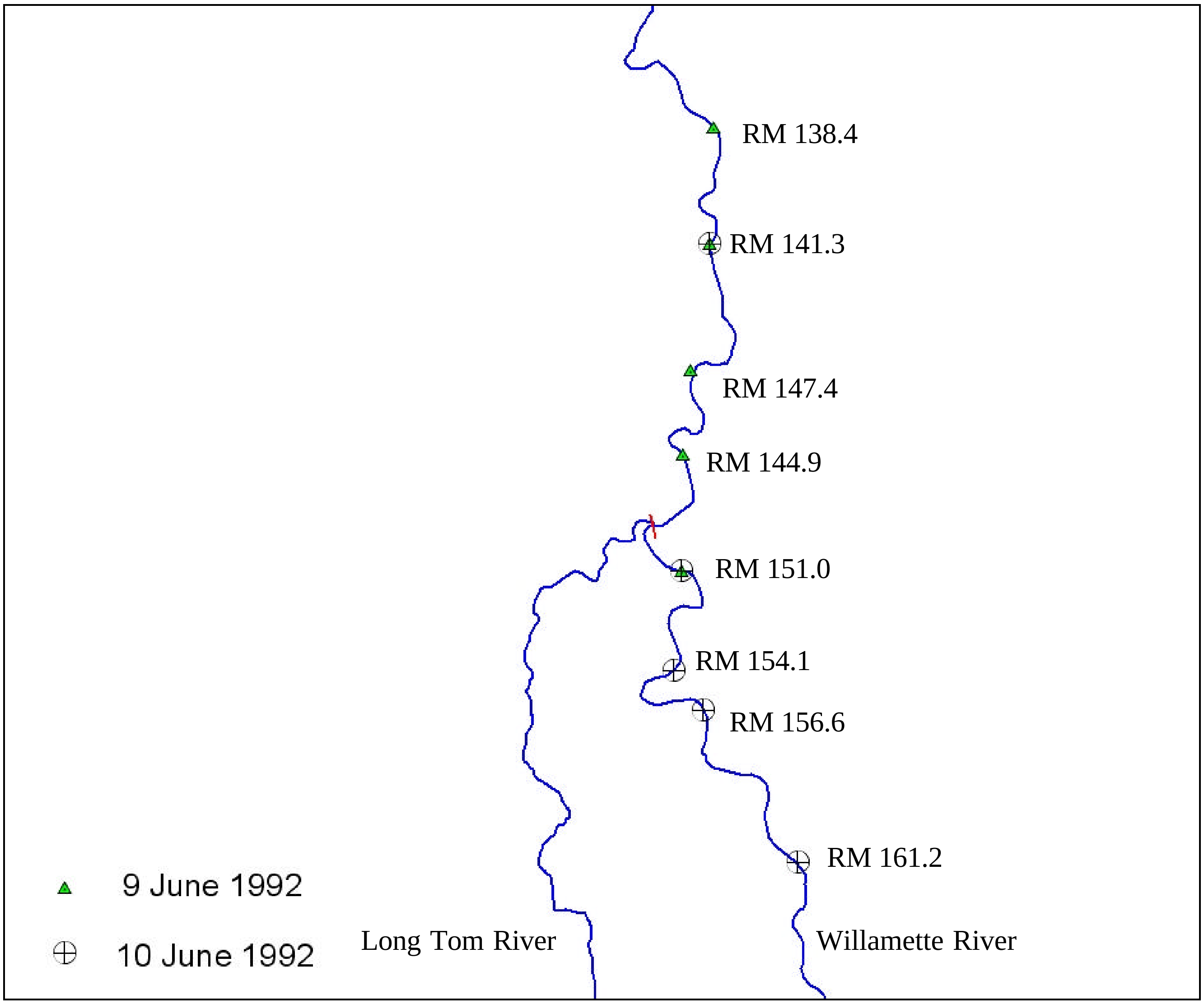

Figure 206: 1992 USGS dye study injection and monitoring sites.

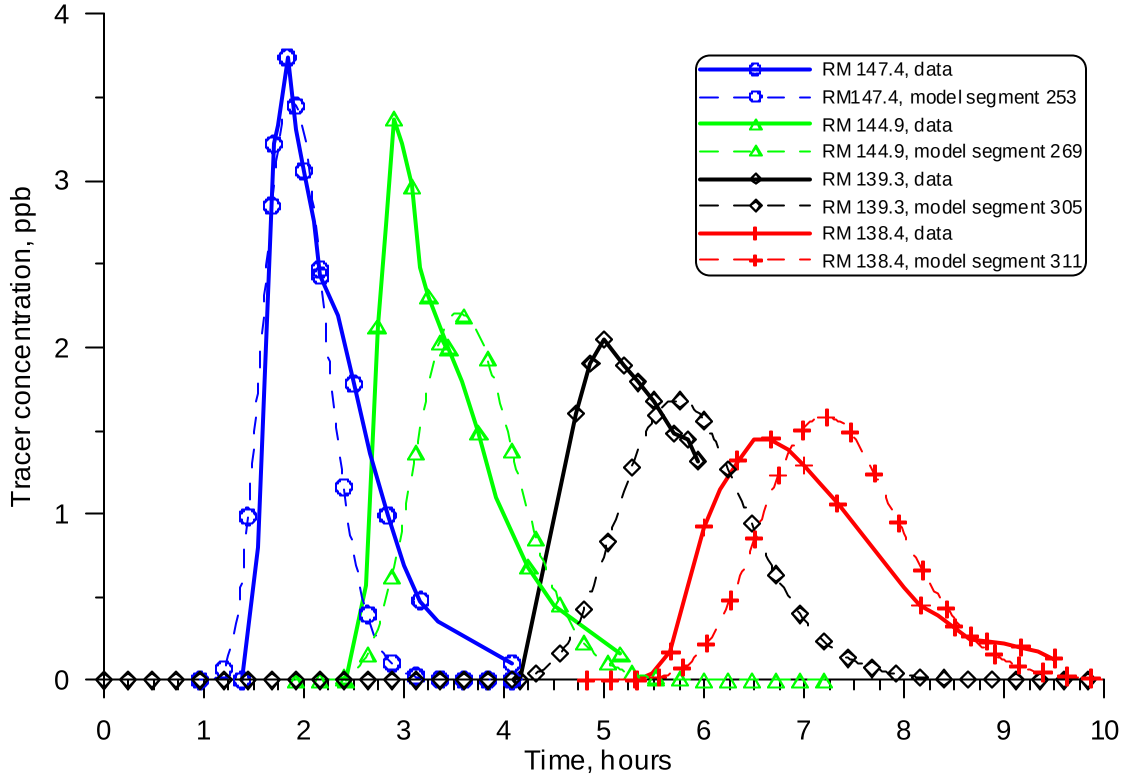

Figure 207: June 9, 1992 dye study model simulation

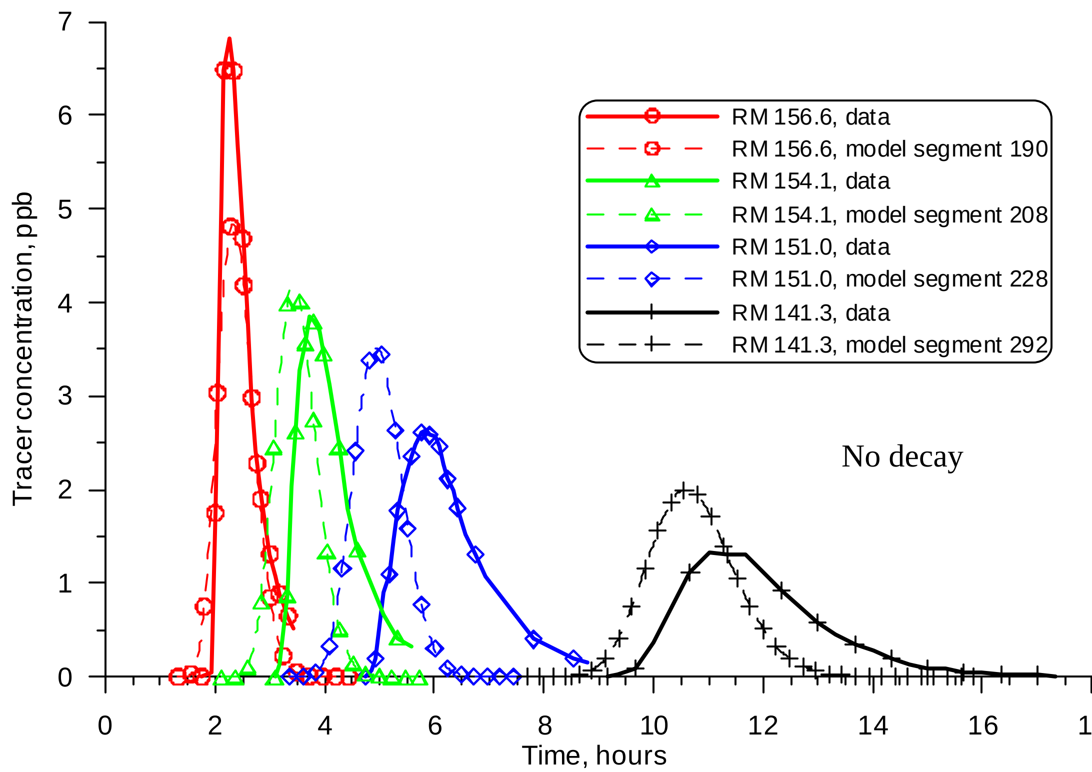

Figure 208: June 10, 1992 dye study model simulation. No decay was simulated

Three 1998 dye study reaches were simulated. The study area, from RM 170 to RM 154, is shown in Figure 209. The injection point for each study was a simulated concentration curve, as opposed to a point injection. The exact injection point used in the physical study was not known. The 1998 studies were investigating hyporheic flow.

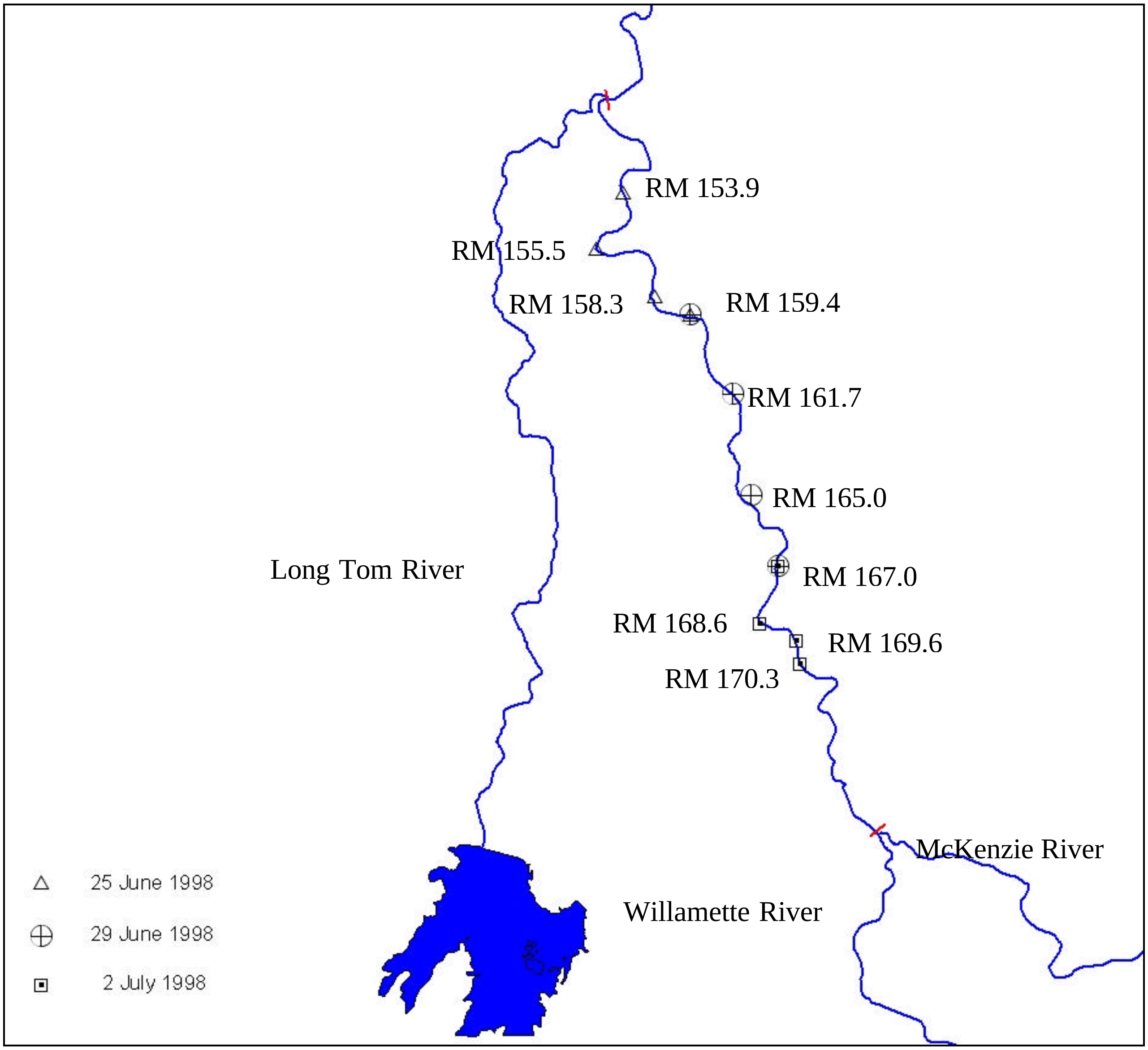

Figure 209: 1998 EPA dye study injection and monitoring sites.

The model-data comparisons are shown in, and Figure 210, Figure 211, Figure 212. Channel bottom friction alone was insufficient to match the data. Since the surface width was constrained by the wetted width data, adjustments to the widths of the lower model layers were used to adjust the travel rates. Once sufficiently close, channel bottom friction was used to fine tune the calibration. Dispersion and decay were adjusted on a per segment basis to match the peak and shape of the dye curves. Calibration of each subreach affected the other subreaches. Typically, the timing of the last subreach could not be met without disturbing the upstream subreach timing.

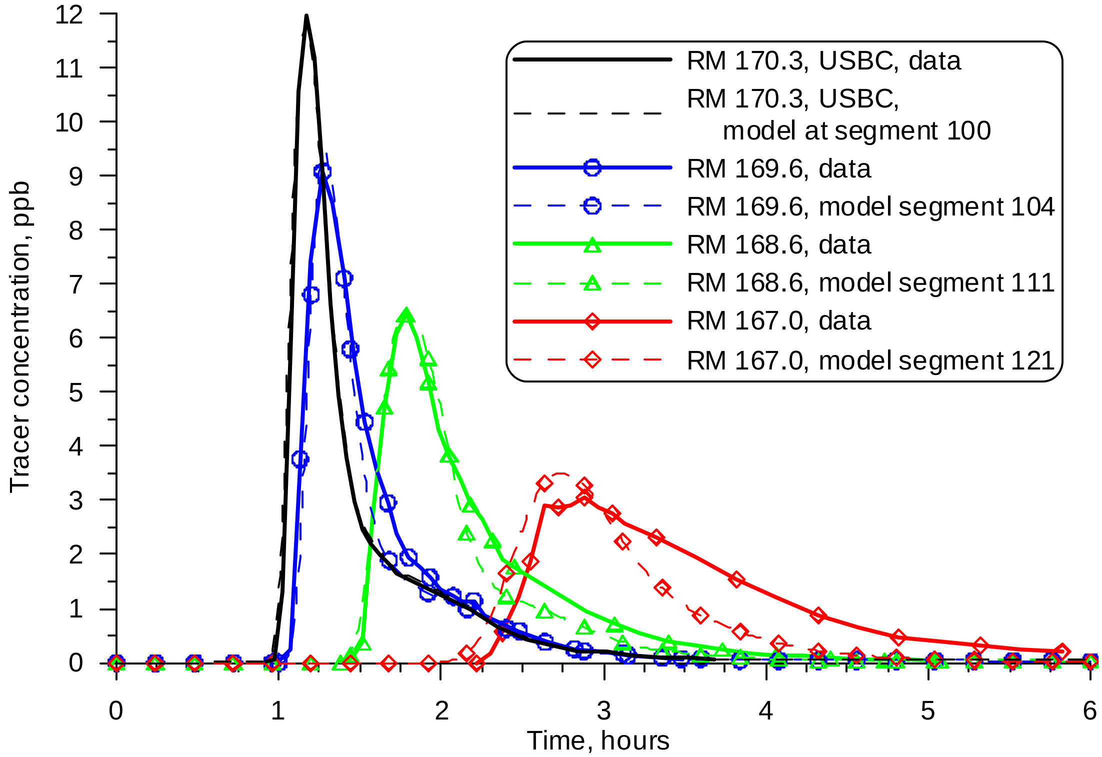

Figure 210: July 2, 1998 dye study model simulation.

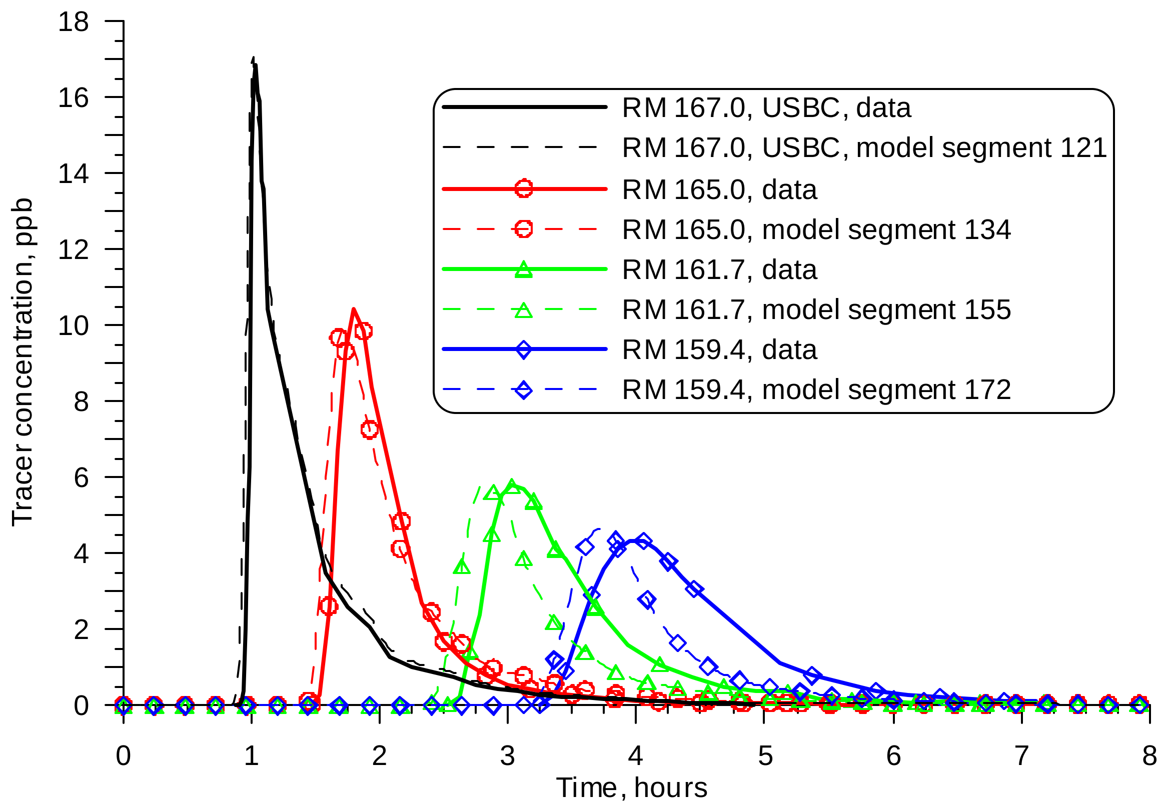

Figure 211: June 25, 1998 dye study model simulation.

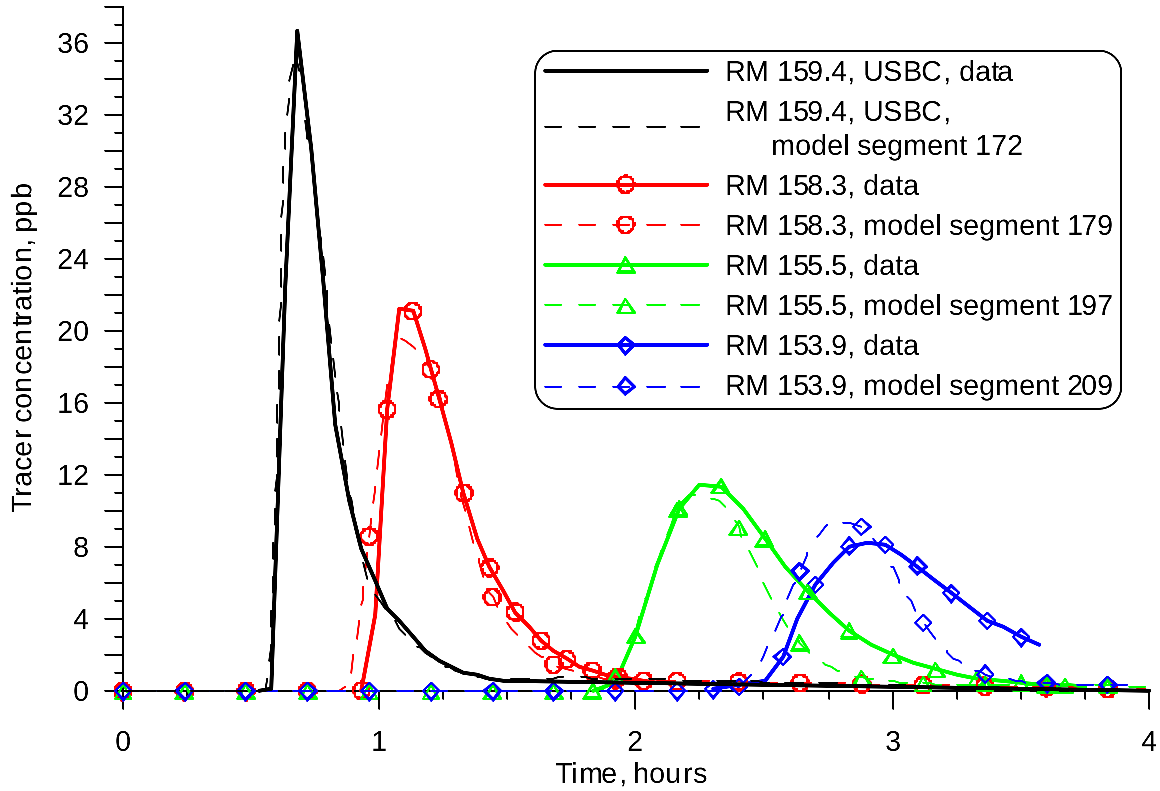

Figure 212: June 29, 1998 dye study model simulation

2002 USGS Willamette River Dye Studies

Two 2002 USGS dye study reaches were simulated. The study area, from RM 142 to RM 108, is shown in Figure 213. The model-data comparison for the June 11, 2002 dye study is shown in Figure 214. The model does a relatively poor job matching the dye data over this reach. The model concentration at the first monitoring station is much lower than the data, indicating that the model has too much numerical dispersion. The timing at the first station also could not be met. The model travel rate over the entire reach is largely insensitive to channel bottom friction and bathymetry due to the flat water surface elevation profile. The model behaves much like a reservoir from RM 128 to 108, and in influenced by the bathymetry at roughly RM121 (upstream of Albany), RM 115, and RM 108 where the channel bottom elevation has a large influence on both the upstream water surface elevation and flow rate. These points are effectively weirs. The calibration of the water surface elevation at Albany, the temperature at Albany and at RM 114 (LASAR 10349), the wetted width, and the June 11, 2002 dye study are all much worse and problematic than other reaches in the model. The issue may lie with the relatively coarse resolution of the bathymetry data, and especially the slope of the model from Corvallis (RM 134) to Salem (RM 85): The model is predominately flat from RM 128 to RM 108, and adjoined by much steeper reaches. Insufficient data exists to determine if this is accurate.

The model-data comparison for the June 12, 2002 dye study is shown in Figure 215. Channel bottom friction alone was insufficient to match the data. Since the surface width was constrained by the wetted width data, adjustments to the widths of the lower model layers were used to adjust the travel rates. Once sufficiently close, channel bottom friction was used to fine tune the calibration. Dispersion and decay were adjusted on a per segment basis to match the peak and shape of the dye curves. Calibration of each subreach affected the other subreaches. The shape of the concentration curve at the last monitoring station could not be met. Even with longitudinal dispersion (DX) values exceeding literature values (500+) for a river of similar size, the curve did not respond enough. A value of DX = 100 was used over the last subreach. This value caused some improvement in curve shape, but higher values had negligible effect. This value is also generally consistent with theory and observation on similar river. Attempts to improve the curve shape using channel bathymetry were not successful. The problem could be lack of detailed bathymetry data over the subreach or the relatively sharp change in the model water surface elevation profile at the end of the subreach where water bodies 3 and 4 connect.

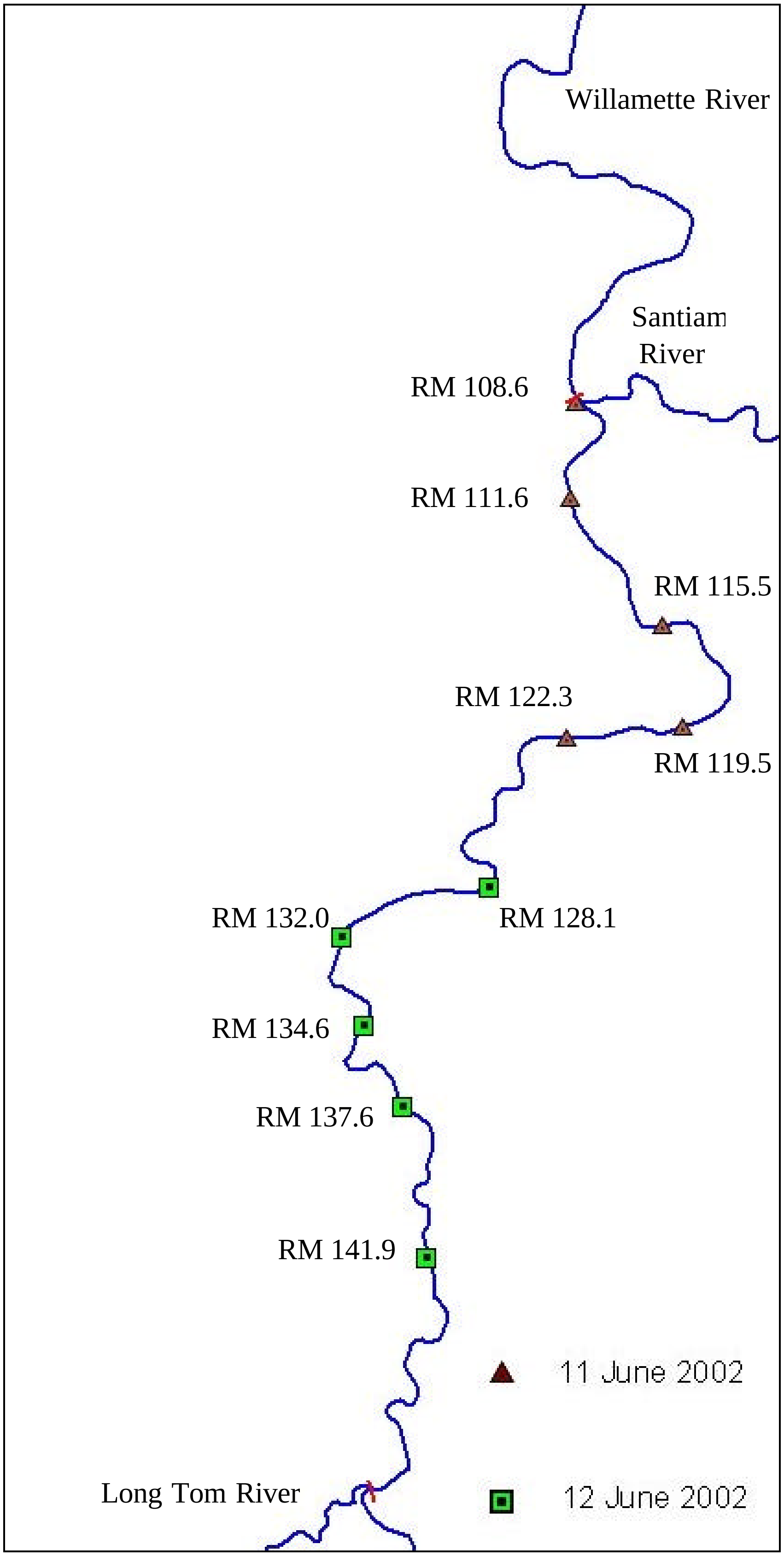

Figure 213: 2002 USGS dye study injection and monitoring sites.

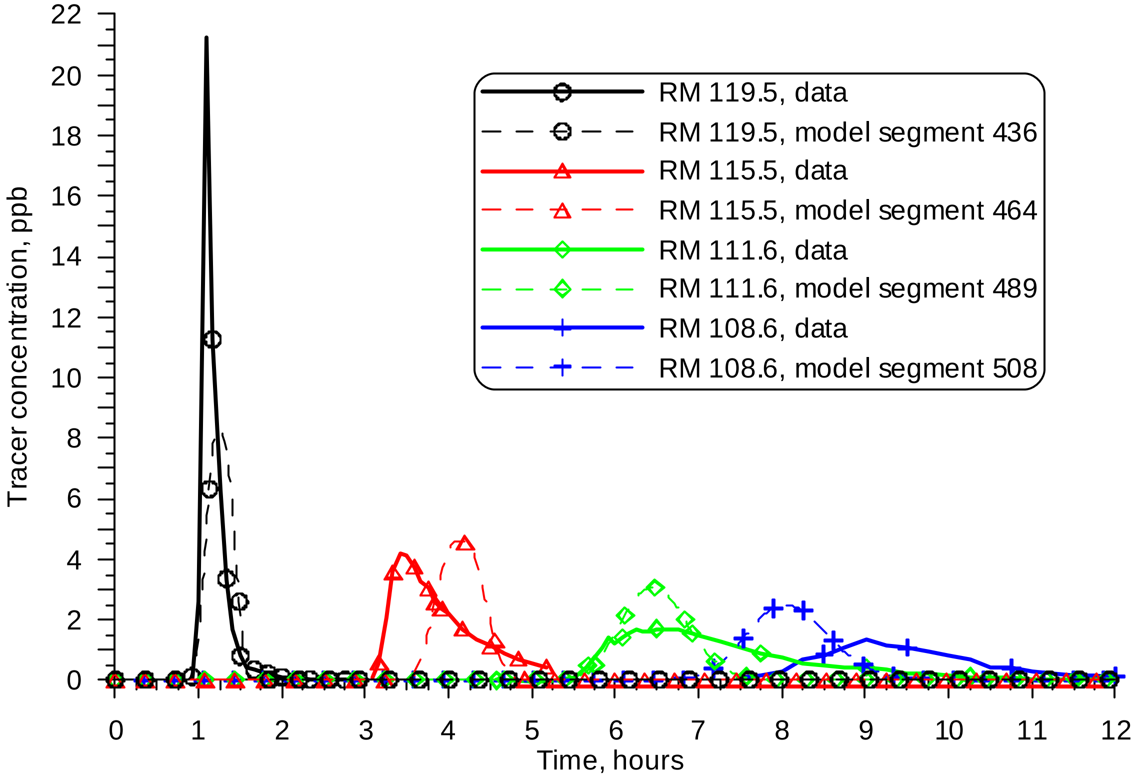

Figure 214: June 11, 2002 dye study model simulation

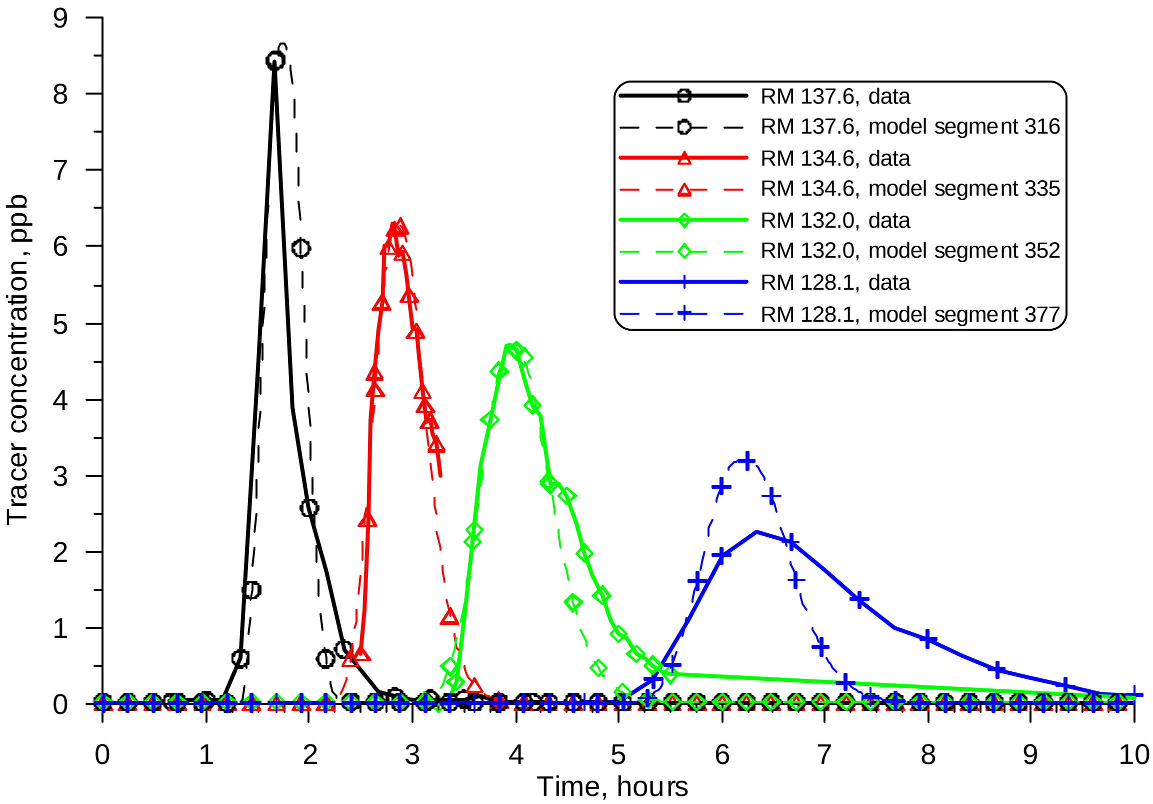

Figure 215: June 12, 2002 dye study model simulation

Water Temperature

Willamette River temperature calibration data was collected from 3 USGS gage stations and 9 Oregon DEQ LASAR sites. The calibration sites locations are shown in Figure 216 and summarized in Table 28.

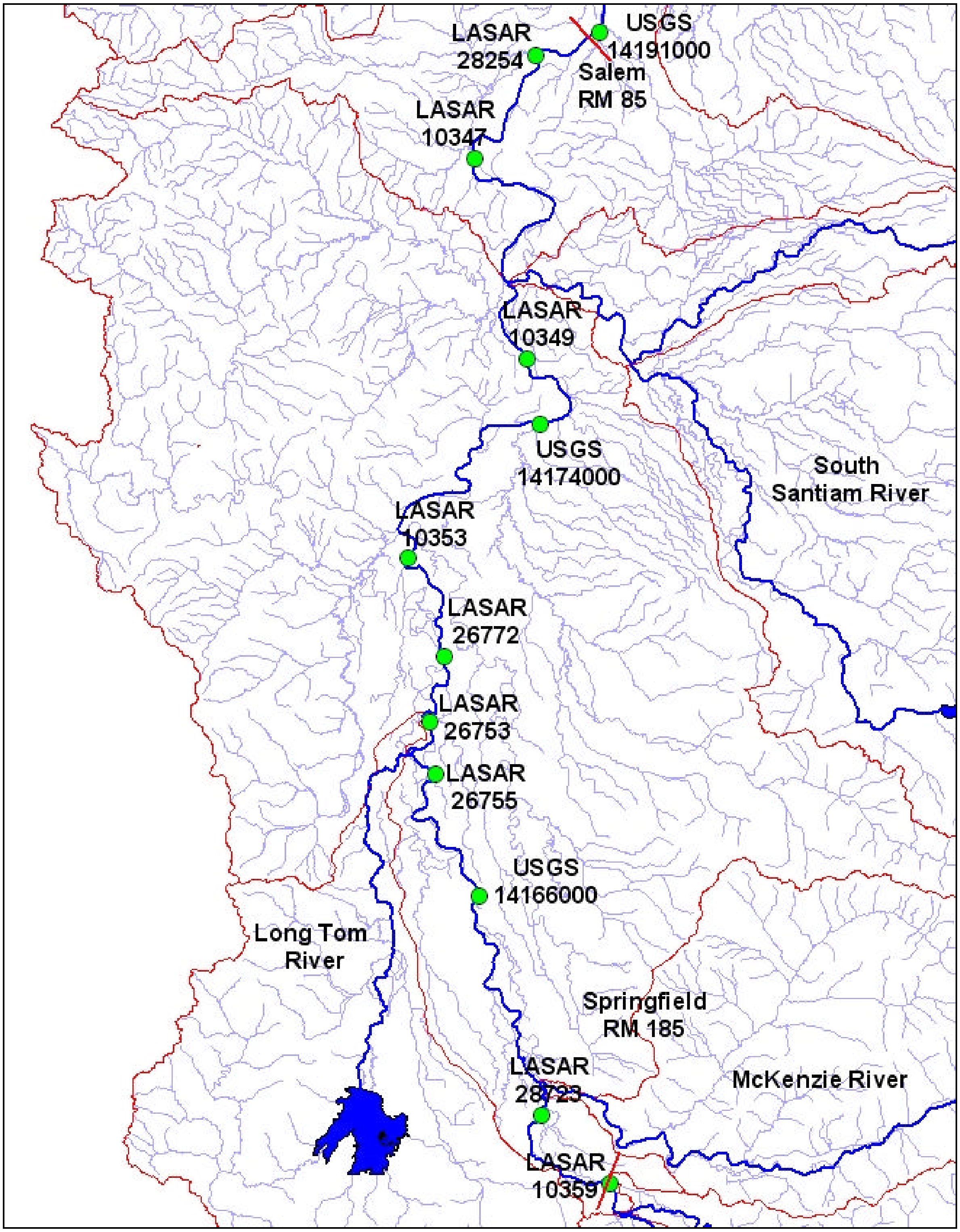

Figure 216: Upper Willamette River temperature calibration site locations

Table 28: Upper Willamette River temperature calibration sites

Site ID	Site Description	RM	Model Segment
LASAR 10359	Willamette River at Springfield	185.25	2
LASAR 28723	Willamette River above McKenzie Confluence	177.74	53
USGS 14166000	Willamette River at Harrisburg	161.98	156
LASAR 26755	Willamette River above Long Tom River	151.55	227
LASAR 26753	Willamette River at RM 147	147.43	255
LASAR 26772	Willamette River at RM 141.7	142.37	287
LASAR 10353	Willamette River at Corvallis Water Intake	135.17	334
USGS 14174000	Willamette River at Albany	120.11	434
LASAR 10349	Willamette River at Conser Road	113.92	476
LASAR 10347	Willamette River at South River Road	96.90	589
LASAR 28254	Willamette River above Rickreall Creek	88.88	643
USGS 14191000	Willamette River at Salem	84.66	666*

Calibrating to the continuous temperature data consisted of first matching the timing of the daily peak temperature, then matching the daily mean temperature, and lastly matching the diurnal variation or the daily minimum and maximum. This process was iterative. Calibration went from upstream to downstream. Unfortunately, the calibration at the upstream site (LASAR 28723), upstream of the confluence with the McKenzie River, was poor. This error propagates downstream. Adjustments made during the temperature calibration generally focused on getting more heat into the water column and reducing the diurnal variation.

The temperature calibration potentially includes several parameters and considerations. The model was found to be insensitive to the parameters of sediment temperature (TSED), light extinction coefficient, and light absorption by the sediment (TSEDF). The topographic and vegetative shade inputs were not used as a calibration tool. Model runs without any shade should roughly a 1 °C increase in water temperature at the downstream end of the model.

The cloud cover and solar radiation data was examined as a calibration tool. Mean differences in results between the solar radiation and cloud cover data were negligible. There were some differences for individual day's temperatures, however. Negligible differences in temperature resulted from applying the solar data at Corvallis in place of the Salem/Gladstone solar data.

The evaporation coefficients (AFW, BFW) were reduced to decrease the rate of heat exchange between the water and atmosphere. This results in a net warming of the water. By reducing evaporation over the full model length, the mean water temperature at Salem was raised ~0.5 °C.

Temperature calibration showed that the McKenzie River tributary inflow temperature first used was too cold. This resulted in the development of new correlations.

Some alterations to the bathymetry were needed to calibrate the model for temperature. Two common adjustments were 1) to speed or slow the flow so that the daily temperature peaks occurred at the correct time of day; and 2) to deepen the channel so that a greater volume of water was being heated, thus reducing the diurnal temperature variation. These alterations were most made throughout the bulk of the model. While surface width influences the amount of solar radiation being absorbed by the water, it was not used as a calibration tool due to the width data which was also a calibration target. The exception is over the first 50 model segments where the channel was deliberately narrowed more than the data suggested to improve the results at LASAR 28723 and USGS 14166000.

Continuous Temperatures

Year 2001

The continuous water temperature statistics for the 2001 model year are reported in Table 29. Statistics were calculated over the calibration period, (6/12/2001 to 9/25/01), excepting period of missing data. The RMS error for all sites was less than 0.9 °C, which indicates that the model is usually within 0.9 °C of the data. The values of the mean error range from –0.221 to 0.490 °C and indicate the range of the bias of the mean temperature, with a slight warm bias to the mean temperature overall.

Table 29: Upper Willamette River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
LASAR 10359	185.3	2	5040	0.02	0.04	0.05
LASAR 28723	177.7	53	2362	-0.18	0.40	0.51
USGS 14166000	162.0	156	5040	0.15	0.62	0.74
LASAR 26755	151.6	227	5040	0.38	0.58	0.74
LASAR 26753	147.4	255	5040	0.49	0.64	0.81
LASAR 26772	142.4	287	5040	0.36	0.60	0.75
LASAR 10353	135.2	334	2520	0.21	0.49	0.62
USGS 14174000	120.2	434	2179	-0.11	0.37	0.47
LASAR 10349	113.9	476	4967	-0.01	0.46	0.58
LASAR 10347	96.9	589	4958	-0.23	0.45	0.56
LASAR 28254	88.9	643	2520	0.04	0.61	0.78
USGS 14191000	84.7	666	600	0.08	0.46	0.56

For all the temperature calibration sites, evaporation was reduced to increase the mean temperature. The continuous temperature results compared to the data at LASAR 28723 are shown in Figure 218. Some physical mechanism is not included in the model or some error in the data exists between the upstream boundary condition (LASAR 10359) at RM 185 and this site at RM 178. The model shows a diurnal variation similar to that of the upstream site, but the data at RM 177 shows a much smaller diurnal variation. At larger flows in 2001, such as after about 9/17/2001, the model and data show strong agreement. The 2002 model data comparison at LASAR 28723 (Figure 230) also has a period of model-data disagreement with regards to the diurnal variation. Unlike the 2001 period of disagreement, the 2002 period does not seem to be related to the flow rate. From conversations with (someone Rob talked to), there is a reach the river between RM 185 and 178 where the channel bottom is largely black basalt. It is unclear if this is related to the model-data disagreement. The 2002 model-data comparison at the downstream site at Harrisburg (RM 162, Figure 231) does not show less agreement during the period when the model-data disagreement is large at LASAR 28723. This suggests that the there could be some inaccuracy in with the data from LASAR 28723. A review of the station gage log did not suggest any problem with the gage installation or operation, however. The gage could be receiving influence from a localized and ephemeral groundwater exchange or surface water input, but there is no additional evidence to support such an assertion. The travel time from LASAR 10259 to LASAR 28723 ranges from 4.3 to 5.3 hours.

The continuous temperature results compared to the data at USGS 14166000 are shown in Figure 219. The model has a larger diurnal variation than the data. The depth over RM 177 to 162 was increased, channel bottom friction was increased, and evaporation was reduced to both raise the mean temperature and reduced the diurnal variation in temperature. A comparison of the model temperature just downstream of the confluence with the McKenzie River to the data at Harrisburg shows that the maximum temperatures are largely unchanged, but the minimum temperatures at Harrisburg are ~2 °C warmer.

There are four temperature calibration sites from RM 162 to 135. The primary calibration issue over this reach was the timing of the temperature peaks. Channel bottom friction and some bathymetry alterations were used. The continuous temperature model-data comparisons for LASAR 26755 are shown in Figure 220, for LASAR 26753 in Figure 221, for LASAR 26772 in Figure 222, and for LASAR 10353 in Figure 223.

The reach from RM 128 to 108 had conflicting calibration targets among the dye study, temperature data, and water level data. The2002 dye study over RM 122 to 115 suggested that the flow should be faster, while the temperature timing at the gage at RM 114 suggested that the temperature timing should be later; the diurnal temperature variation suggested the channel should be deeper. The flow-water surface elevation data at RM 120 (Albany) suggested that the lower layers needed to be narrower. A combination of narrowing the lowest layers upstream of Albany, removing hydraulic restrictions in the dye study reach and around RM 107—which controlled much of the upstream system—and widening the channel downstream of Albany allowed for a general fit of all the data. The continuous temperature model-data comparisons for USGS 14174000 are shown in Figure 224, and for LASAR 10349 in Figure 225.

The reach from RM 108 to 85 required an increase in the mean temperature and decrease in the diurnal temperature variation. Attempts to narrow the lower layers to increase depth and thus decrease the diurnal variation met with little success. Since the downstream end was governed by a model spillway, the reach from RM 96 to 85 was acting largely like a reservoir. The lower layers over this reach were widened to provide an additional volume of water to be heated, and succeeded in decreasing the diurnal variation. The timing of the temperature peaks at LASAR 10347 was adjusted using by removing high points in the bathymetry over RM 105 to 97. The continuous temperature model-data comparisons for LASAR 10347 are shown in Figure 226, for LASAR 28254 in Figure 227, and for USGS 14191000 in Figure 228. The temperature gage at Salem is roughly 1 km downstream from the last model segment, and no data was available from 7/2/2001 to 9/20/2001. Temperature calibration for model year 2001 and 2002 was conducted simultaneously.

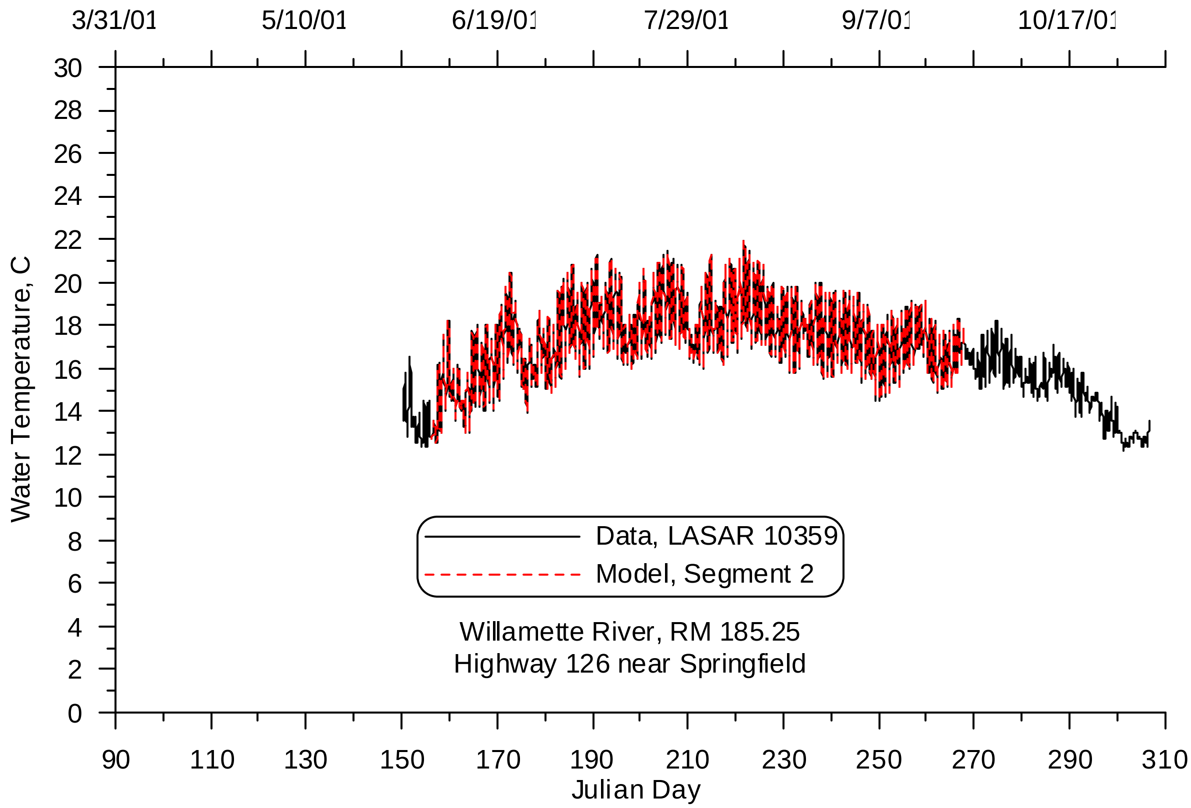

Figure 217: Upper Willamette River near Springfield model-data continuous temperature comparison, 2001

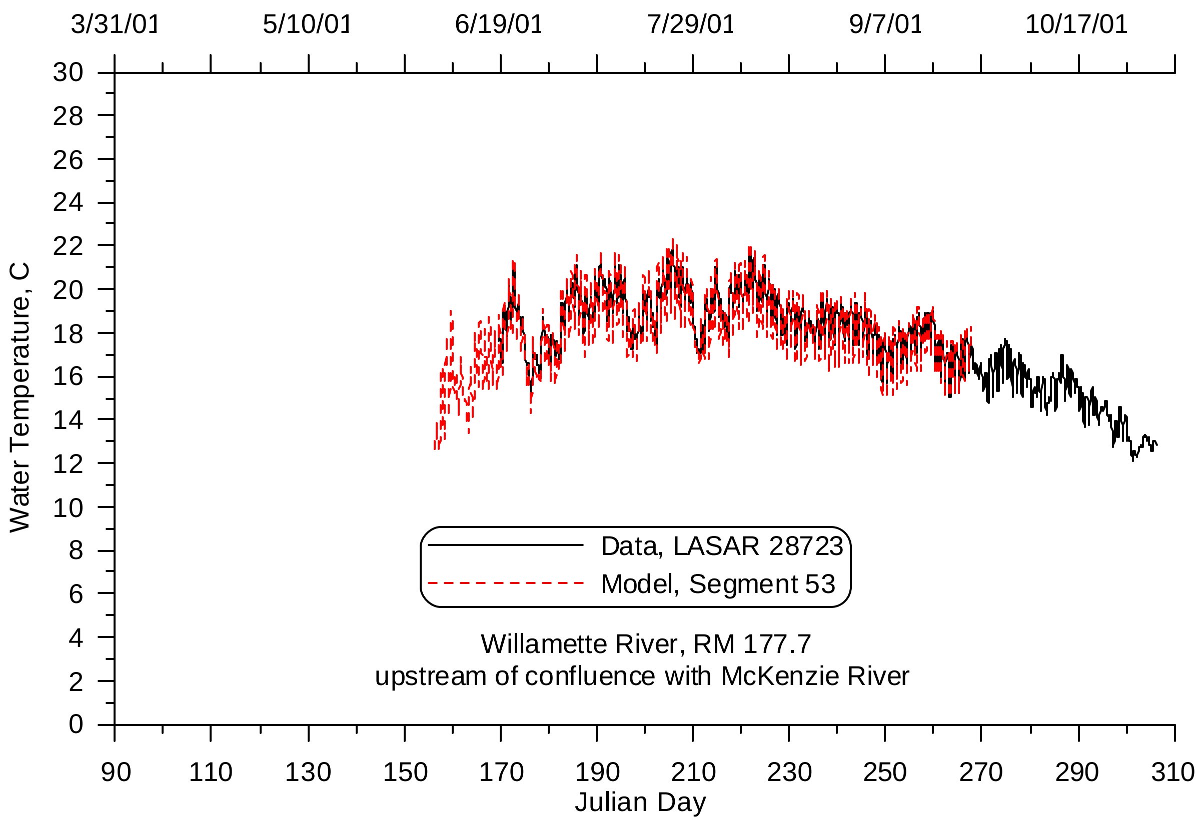

Figure 218: Upper Willamette River above McKenzie River model-data continuous temperature comparison, 2001

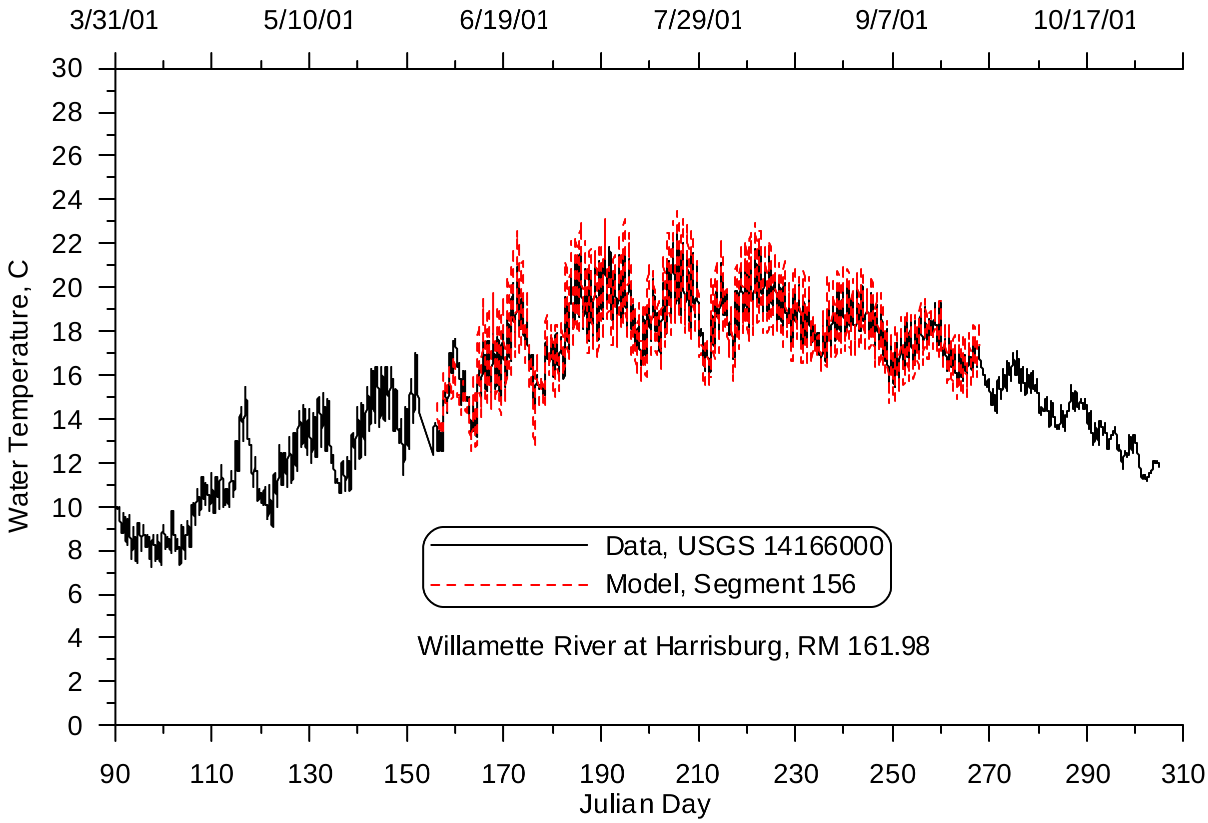

Figure 219: Upper Willamette River at Harrisburg model-data continuous temperature comparison, 2001

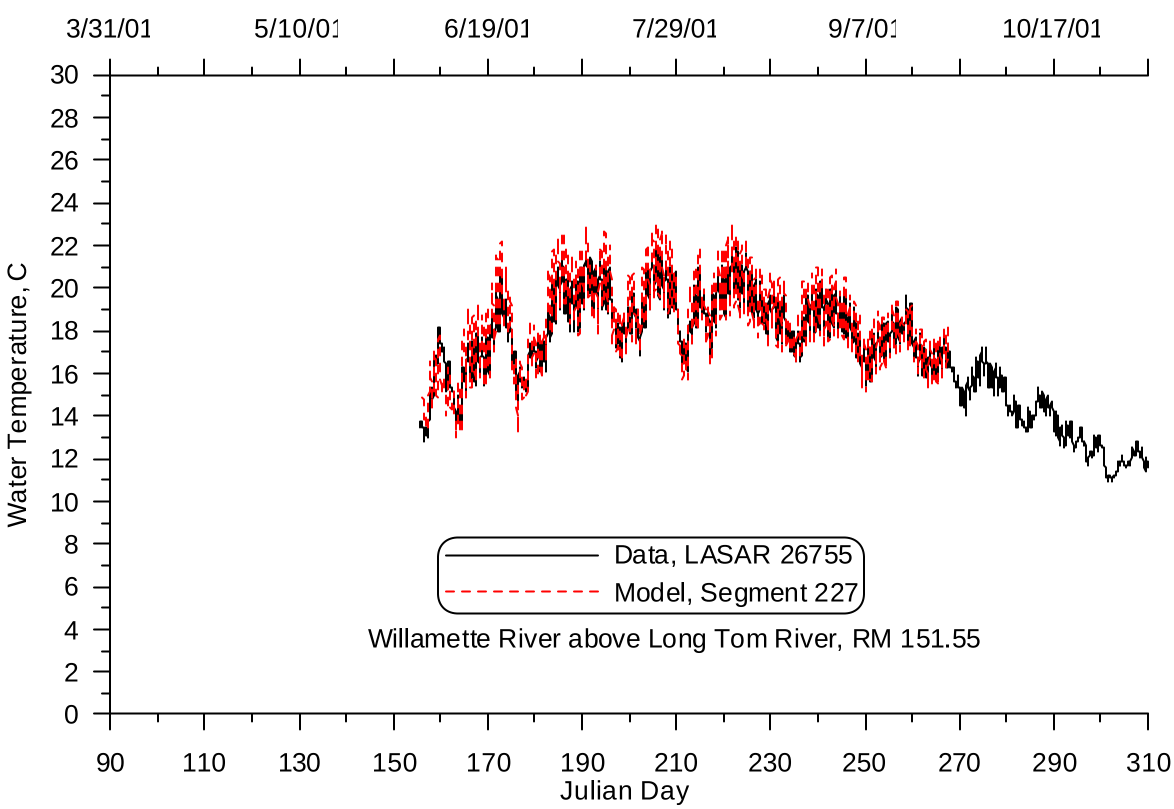

Figure 220: Upper Willamette River above Long Tom River model-data continuous temperature comparison, 2001

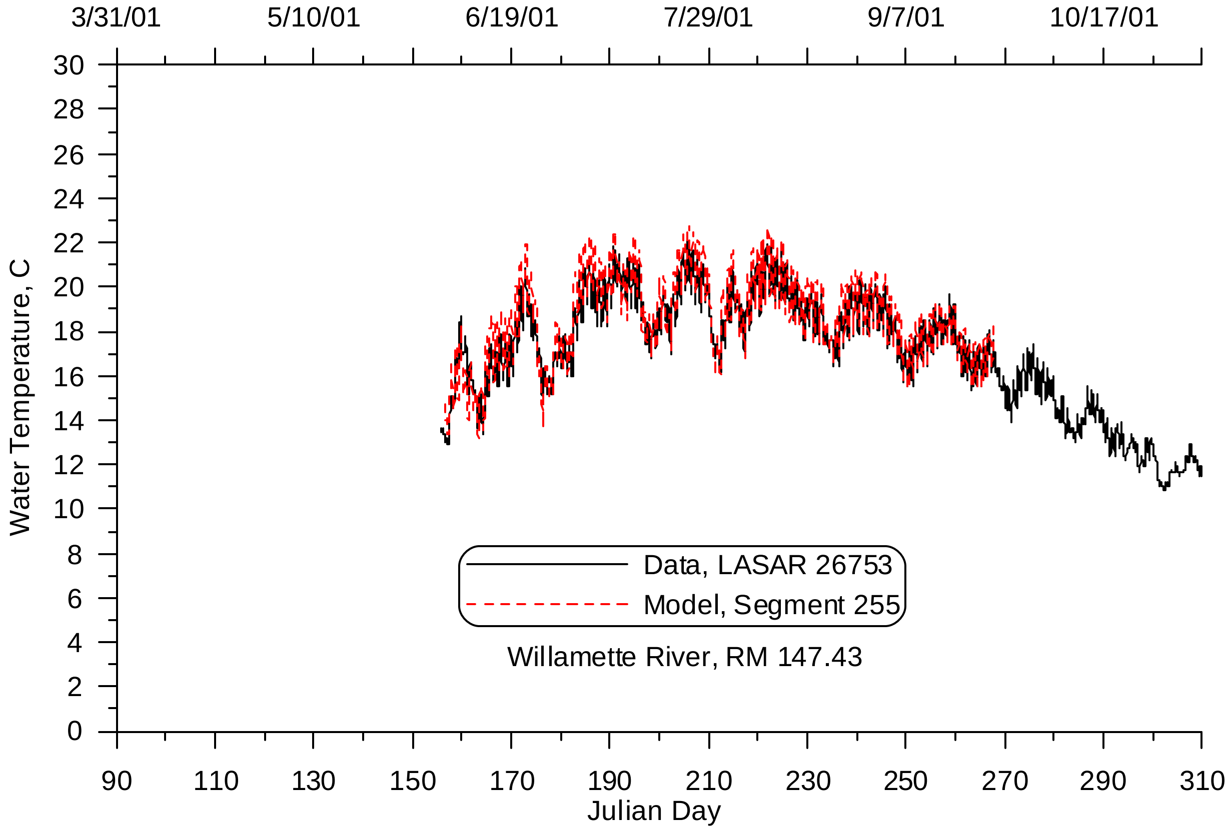

Figure 221: Upper Willamette River at RM 147.4 model-data continuous temperature comparison, 2001

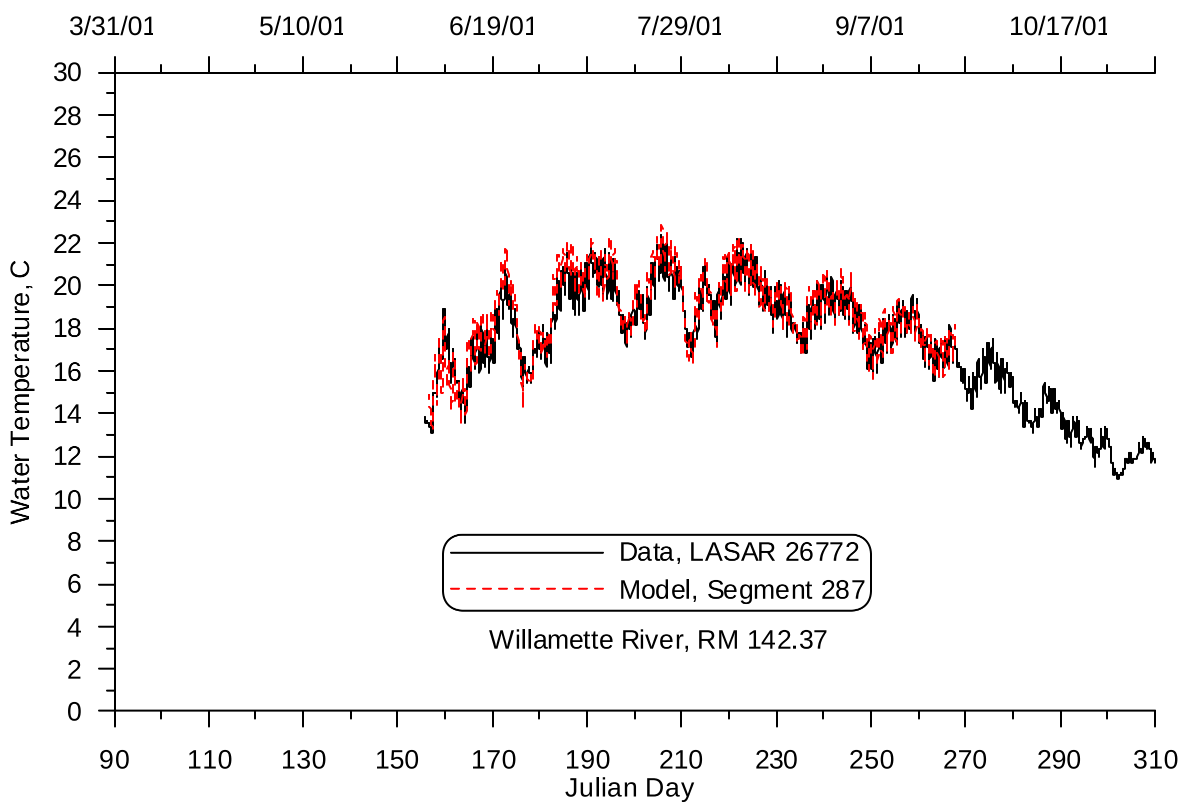

Figure 222: Upper Willamette River at RM 142.4 model-data continuous temperature comparison, 2001

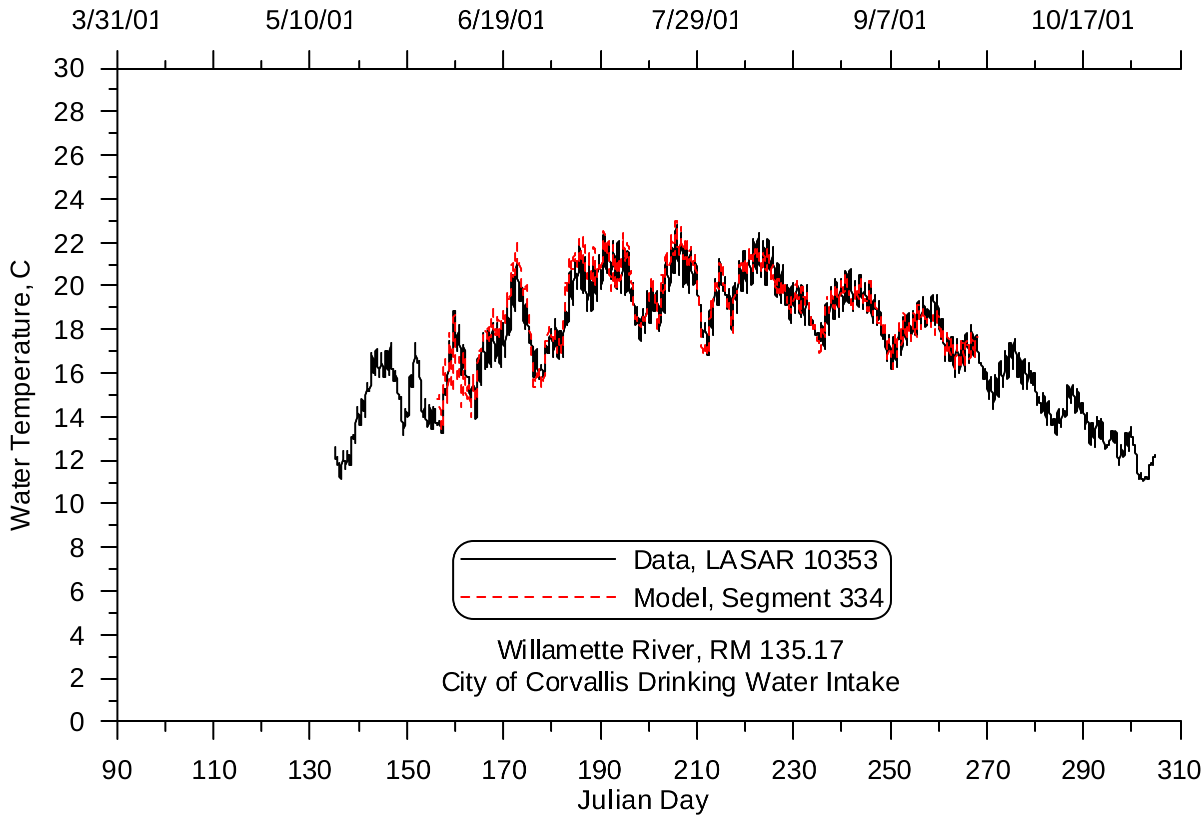

Figure 223: Upper Willamette River at Corvallis model-data continuous temperature comparison, 2001

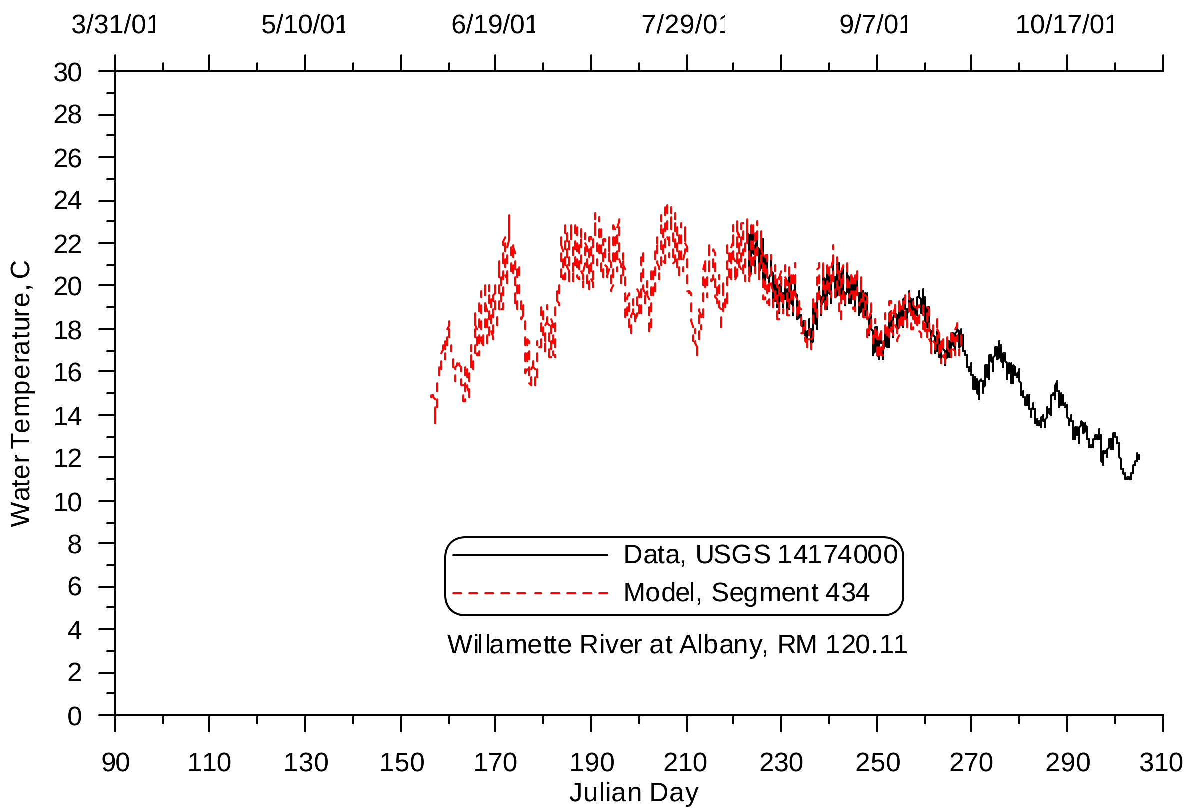

Figure 224: Upper Willamette River at Albany model-data continuous temperature comparison, 2001

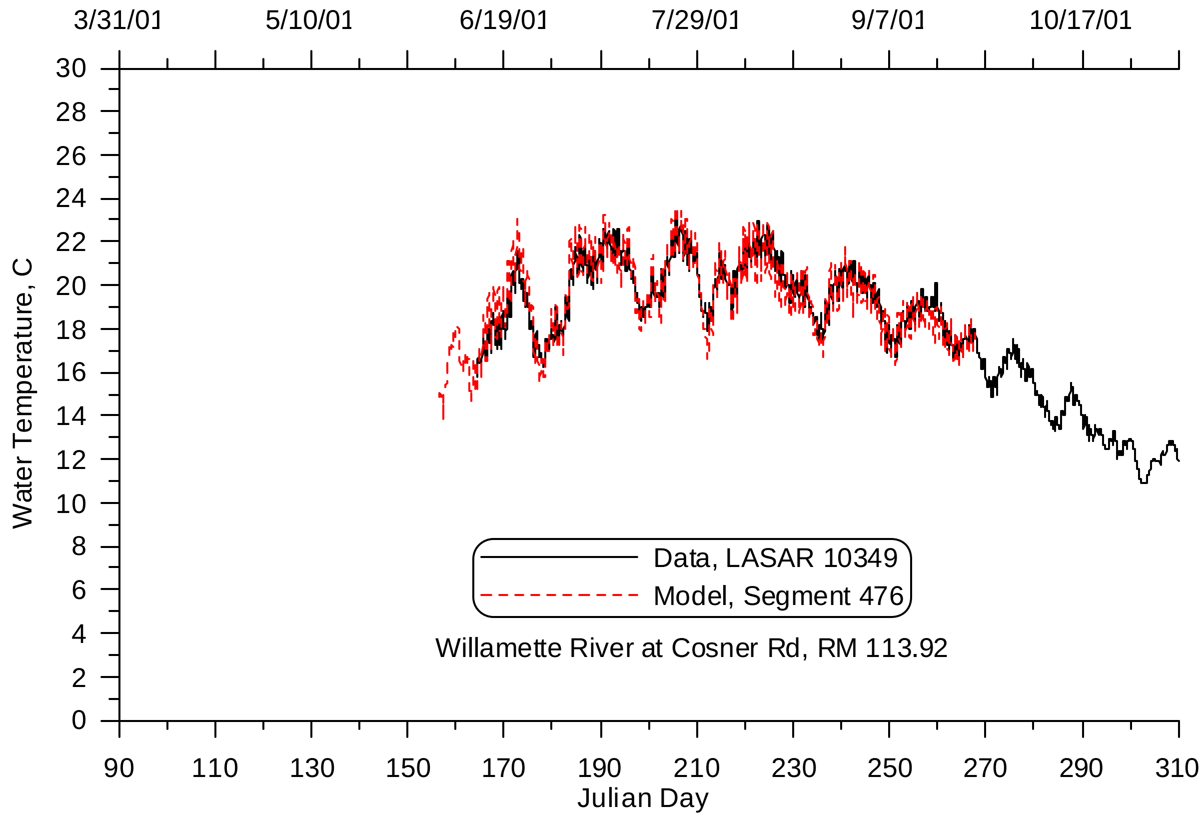

Figure 225: Upper Willamette River at Conser Rd model-data continuous temperature comparison, 2001

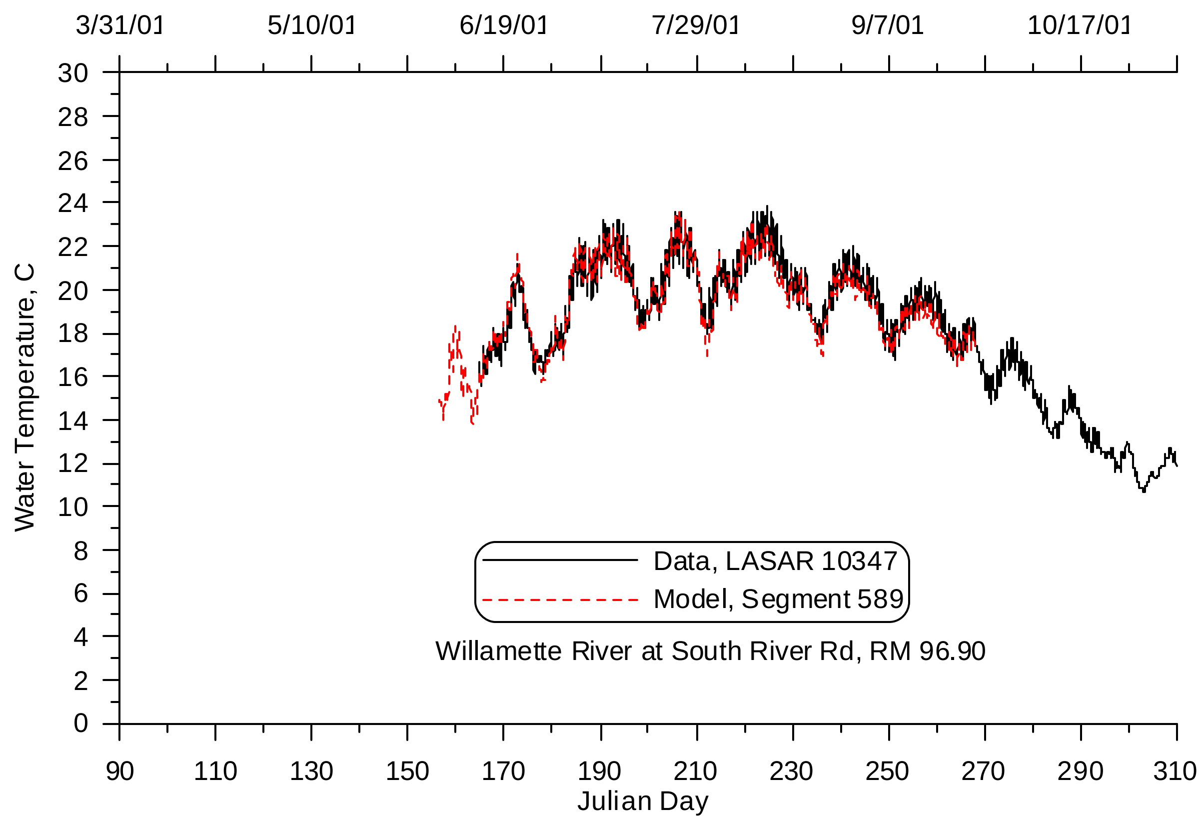

Figure 226: Upper Willamette River at South River Rd model-data continuous temperature comparison, 2001

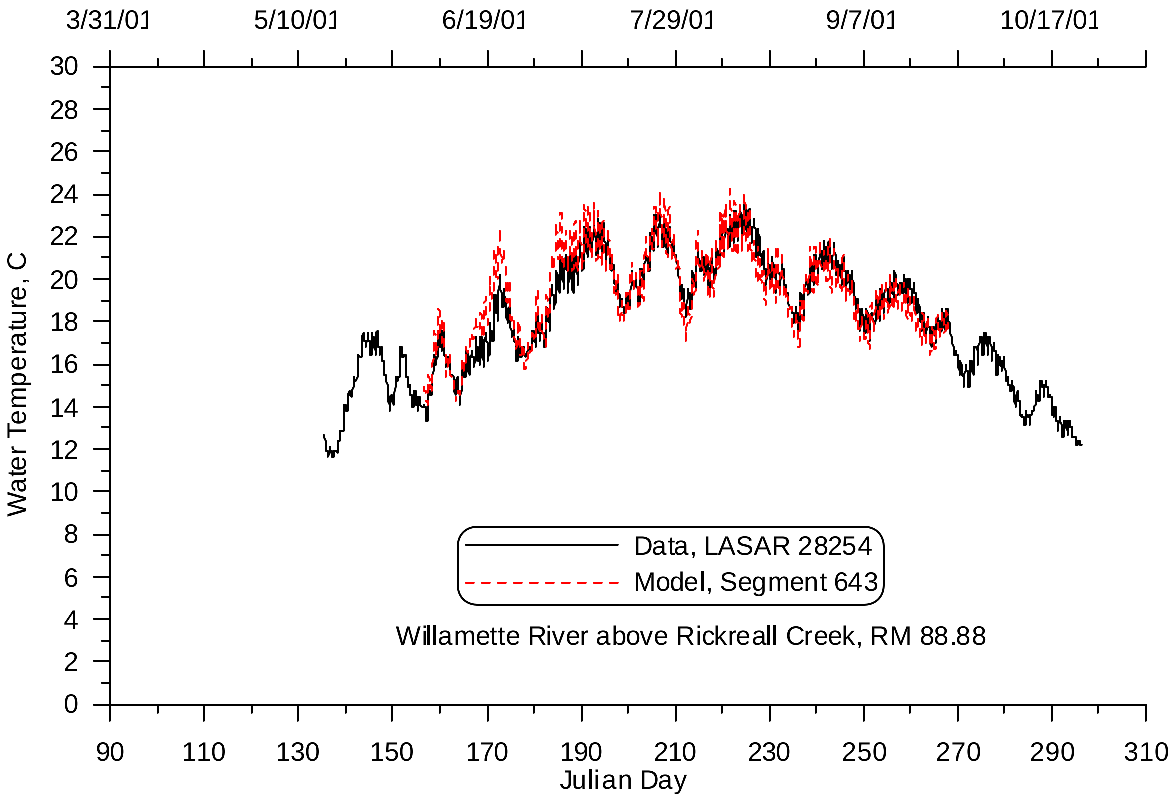

Figure 227: Upper Willamette River above Rickreall Creek model-data continuous temperature comparison, 2001

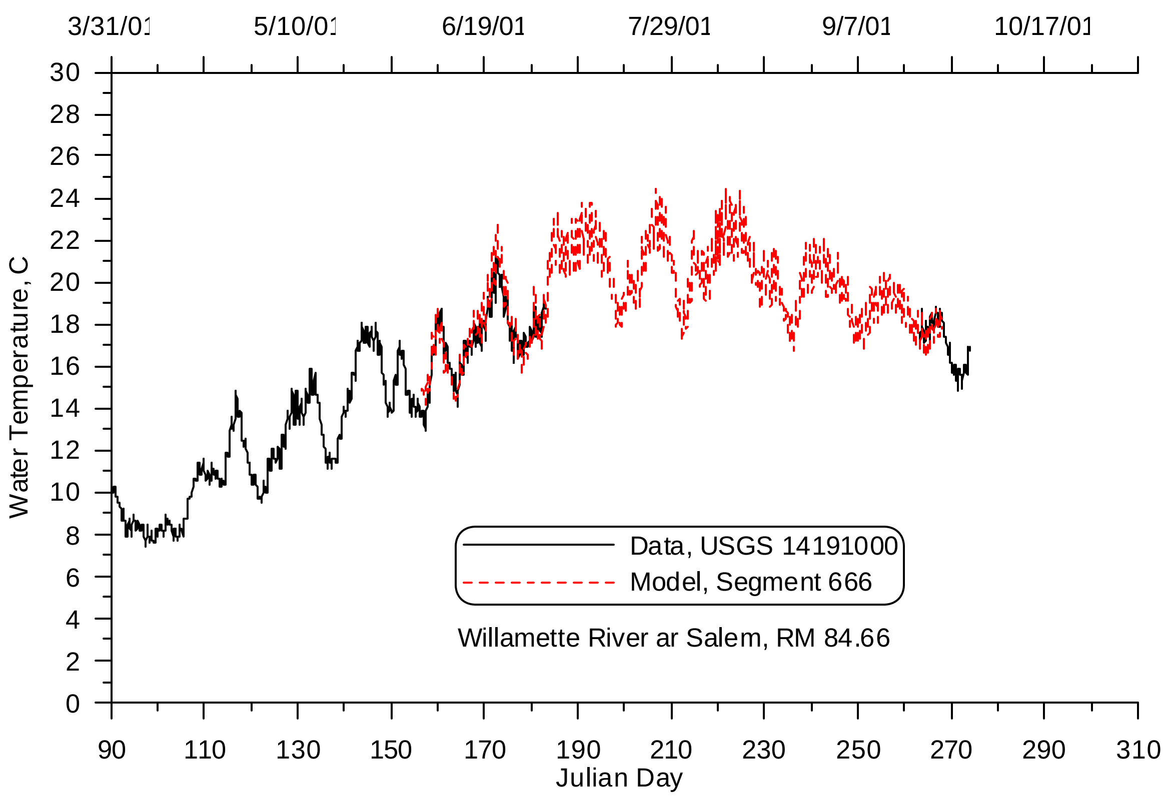

Figure 228: Upper Willamette River at Salem model-data continuous temperature comparison, 2001

Year 2002

There were no temperature data at Salem (USGS 14191000) for 2002. The continuous water temperature statistics for the 2002 model year are reported in Table 30. Statistics were calculated over the calibration period, (6/4/2002 to 10/1/02), excepting period of missing data. The RMS error for all sites was less than 0.8 °C, which indicates that the model is usually within 0.8 °C of the data. The values of the mean error range from –0.572 to -0.208 °C and indicate a cold bias to the 2002 model. This is in contrast to the 2001 model which has a slight warm bias.

Table 30: Upper Willamette River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 10359	185.3	2	5740	0.01	0.13	0.16
LASAR 28723	177.7	53	2880	-0.21	0.46	0.58
USGS 14166000	162.0	156	5760	-0.57	0.61	0.73
LASAR 26755	151.6	227	5760	-0.38	0.45	0.56
LASAR 26753	147.4	255	5760	-0.21	0.39	0.48
LASAR 26772	142.4	287	3882	-0.39	0.49	0.59
LASAR 10353	135.2	334	2880	-0.39	0.46	0.56
USGS 14174000	120.2	434	5760	-0.50	0.54	0.65
LASAR 10349	113.9	476	5633	-0.46	0.51	0.62
LASAR 10347	96.9	589	5302	-0.42	0.45	0.53
LASAR 28254	88.9	643	2032	-0.52	0.60	0.74

For all the temperature calibration sites, evaporation was reduced to increase the mean temperature. The continuous temperature results compared to the data at LASAR 28723 are shown in Figure 230. Some physical mechanism is not included in the model or some error in the data exists between the upstream boundary condition (LASAR 10359) at RM 185 and this site at RM 178. The model shows a diurnal variation similar to that of the upstream site, but the data at RM 177 shows a much smaller diurnal variation. At larger flows in 2001, such as after about 9/17/2001, the model and data show strong agreement. The 2002 model data comparison at LASAR 28723 (Figure 230) also has a period of model-data disagreement with regards to the diurnal variation. Unlike the 2001 period of disagreement, the 2002 period does not seem to be related to the flow rate. From conversations with (someone Rob talked to), there is a reach the river between RM 185 and 178 where the channel bottom is largely black basalt. It is unclear if this is related to the model-data disagreement. The 2002 model-data comparison at the downstream site at Harrisburg (RM 162, Figure 231) does not show less agreement during the period when the model-data disagreement is large at LASAR 28723. This suggests that the there could be some inaccuracy in with the data from LASAR 28723. A review of the station gage log did not suggest any problem with the gage installation or operation, however. The gage could be receiving influence from a localized and ephemeral groundwater exchange or surface water input, but there is no additional evidence to support such an assertion. The travel time from LASAR 10259 to LASAR 28723 ranges from 4.3 to 5.3 hours.

The continuous temperature results compared to the data at USGS 14166000 are shown in Figure 231. The model has a larger diurnal variation than the data. The depth over RM 177 to 162 was increased, channel bottom friction was increased, and evaporation was reduced to both raise the mean temperature and reduced the diurnal variation in temperature. A comparison of the model temperature just downstream of the confluence with the McKenzie River to the data at Harrisburg shows that the maximum temperatures are largely unchanged, but the minimum temperatures at Harrisburg are ~2 °C warmer.

There are four temperature calibration sites from RM 162 to 135. The primary calibration issue over this reach was the timing of the temperature peaks. Channel bottom friction and some bathymetry alterations were used. The continuous temperature model-data comparisons for LASAR 26755 are shown in Figure 232, for LASAR 26753 in Figure 233, for LASAR 26772 in Figure 234, and for LASAR 10353 in Figure 235.

The reach from RM 128 to 108 had conflicting calibration targets among the dye study, temperature data, and water level data. The2002 dye study over RM 122 to 115 suggested that the flow should be faster, while the temperature timing at the gage at RM 114 suggested that the temperature timing should be later; the diurnal temperature variation suggested the channel should be deeper. The flow-water surface elevation data at RM 120 (Albany) suggested that the lower layers needed to be narrower. A combination of narrowing the lowest layers upstream of Albany, removing hydraulic restrictions in the dye study reach and around RM 107—which controlled much of the upstream system—and widening the channel downstream of Albany allowed for a general fit of all the data. The continuous temperature model-data comparisons for USGS 14174000 are shown in Figure 236, and for LASAR 10349 in Figure 237.

The reach from RM 108 to 85 required an increase in the mean temperature and decrease in the diurnal temperature variation. Attempts to narrow the lower layers to increase depth and thus decrease the diurnal variation met with little success. Since the downstream end was governed by a model spillway, the reach from RM 96 to 85 was acting largely like a reservoir. The lower layers over this reach were widened to provide an additional volume of water to be heated, and succeeded in decreasing the diurnal variation. The timing of the temperature peaks at LASAR 10347 was adjusted using by removing high points in the bathymetry over RM 105 to 97. The continuous temperature model-data comparisons for LASAR 10347 are shown in Figure 238, for LASAR 28254 in Figure 239. No temperature data was available over the 2002 calibration period for USGS 14191000. Temperature calibration for model year 2001 and 2002 was conducted simultaneously.

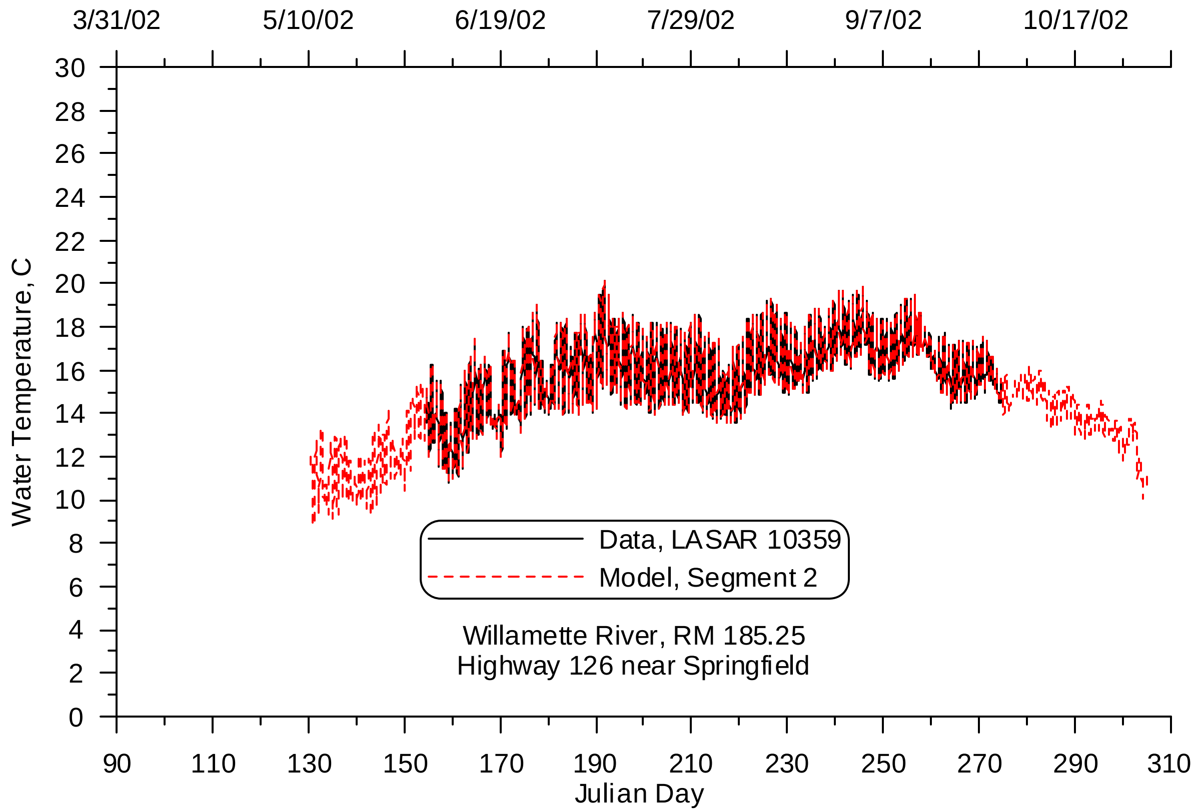

Figure 229: Upper Willamette River near Springfield model-data continuous temperature comparison, 2002

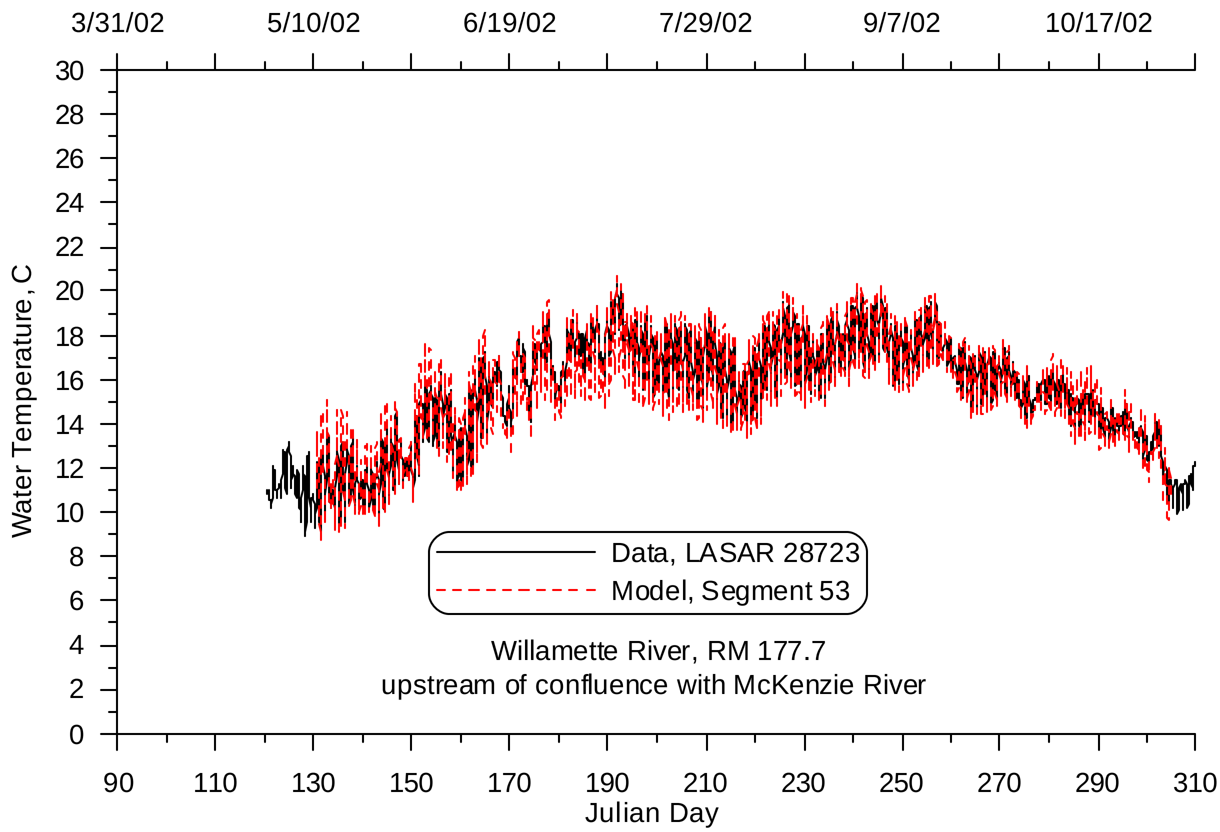

Figure 230: Upper Willamette River above McKenzie River model-data continuous temperature comparison, 2002

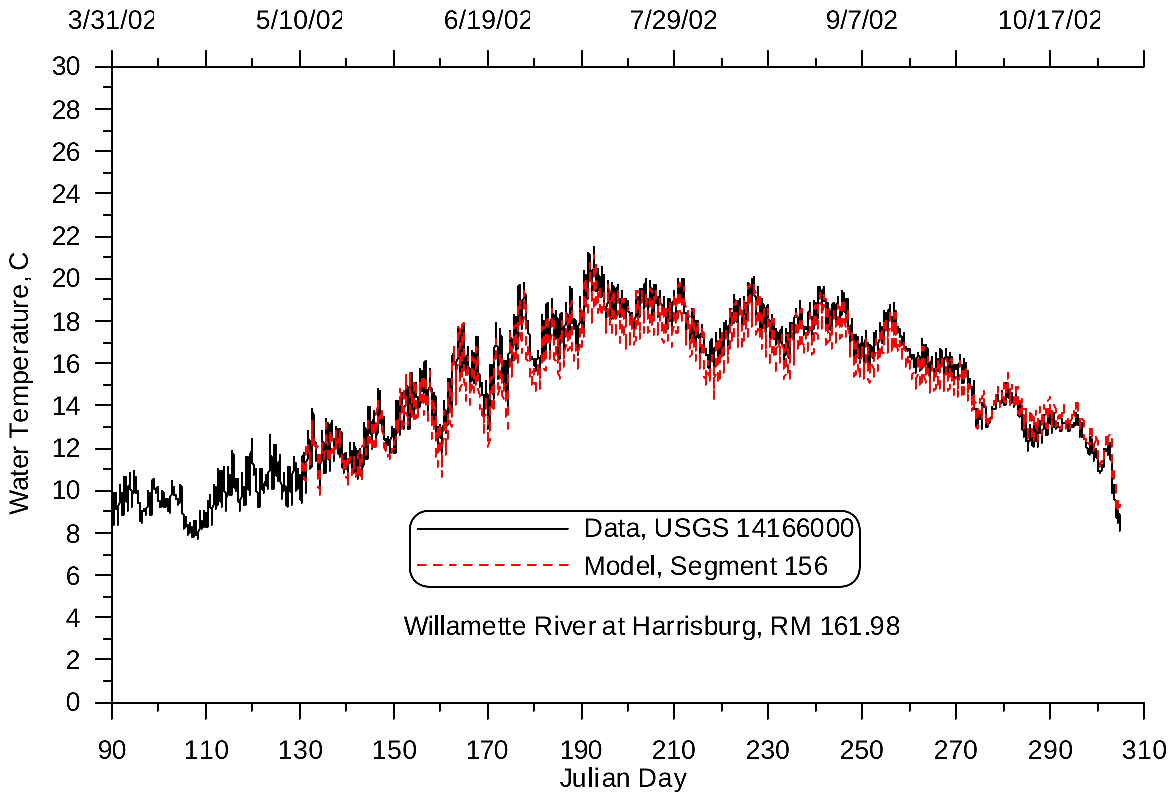

Figure 231: Upper Willamette River at Harrisburg model-data continuous temperature comparison, 2002

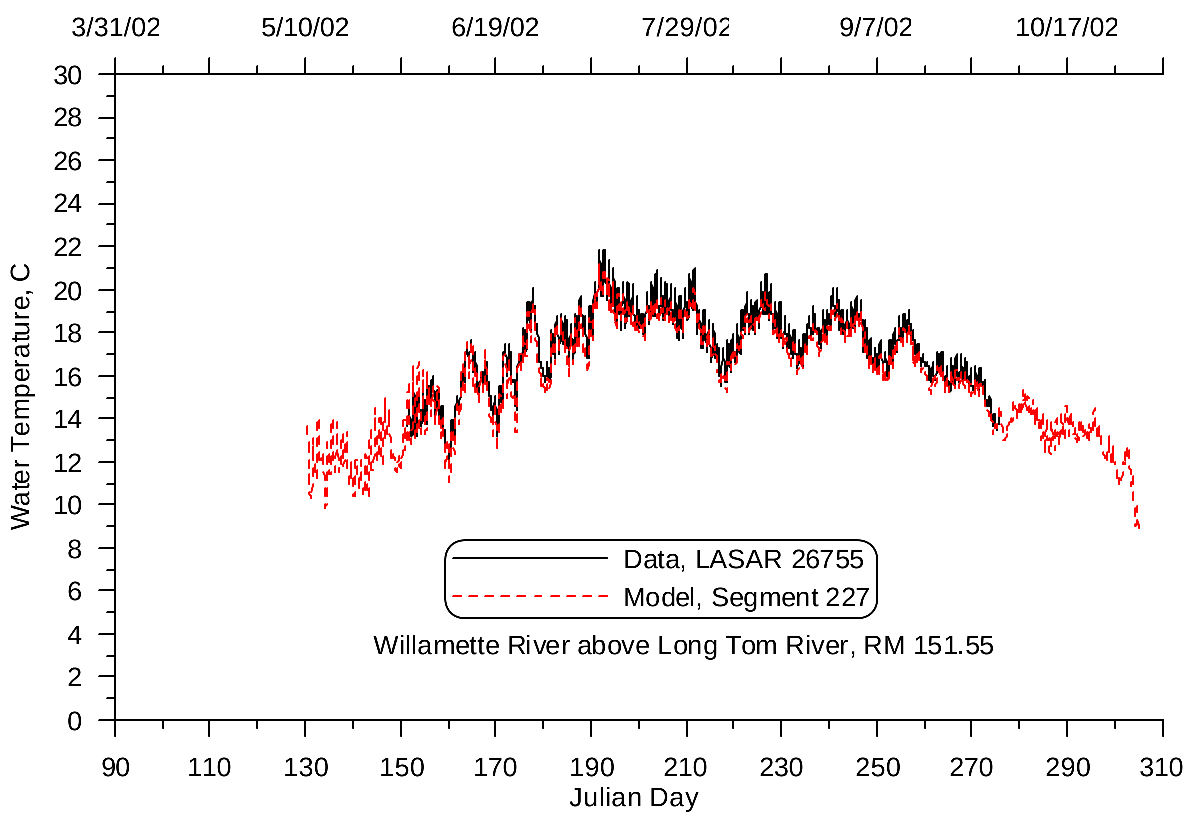

Figure 232: Upper Willamette River above Long Tom River model-data continuous temperature comparison, 2002

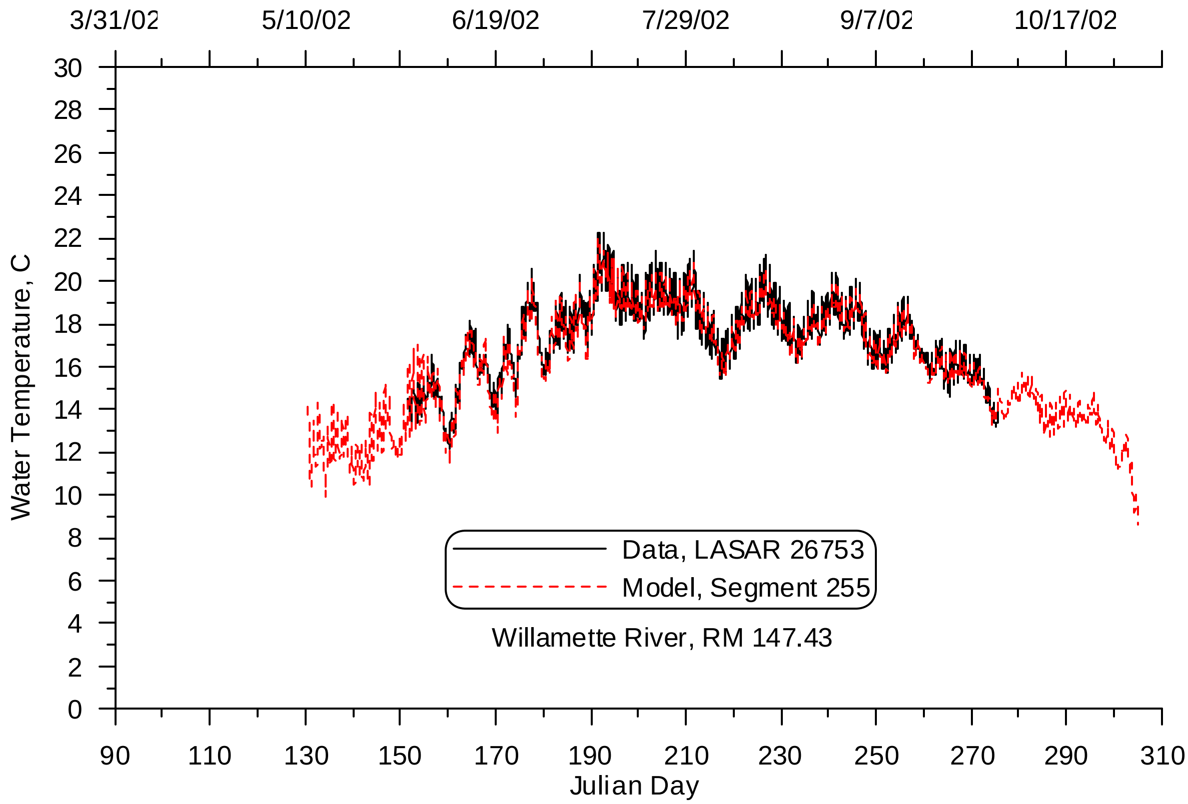

Figure 233: Upper Willamette River at RM 147.4 model-data continuous temperature comparison, 2002

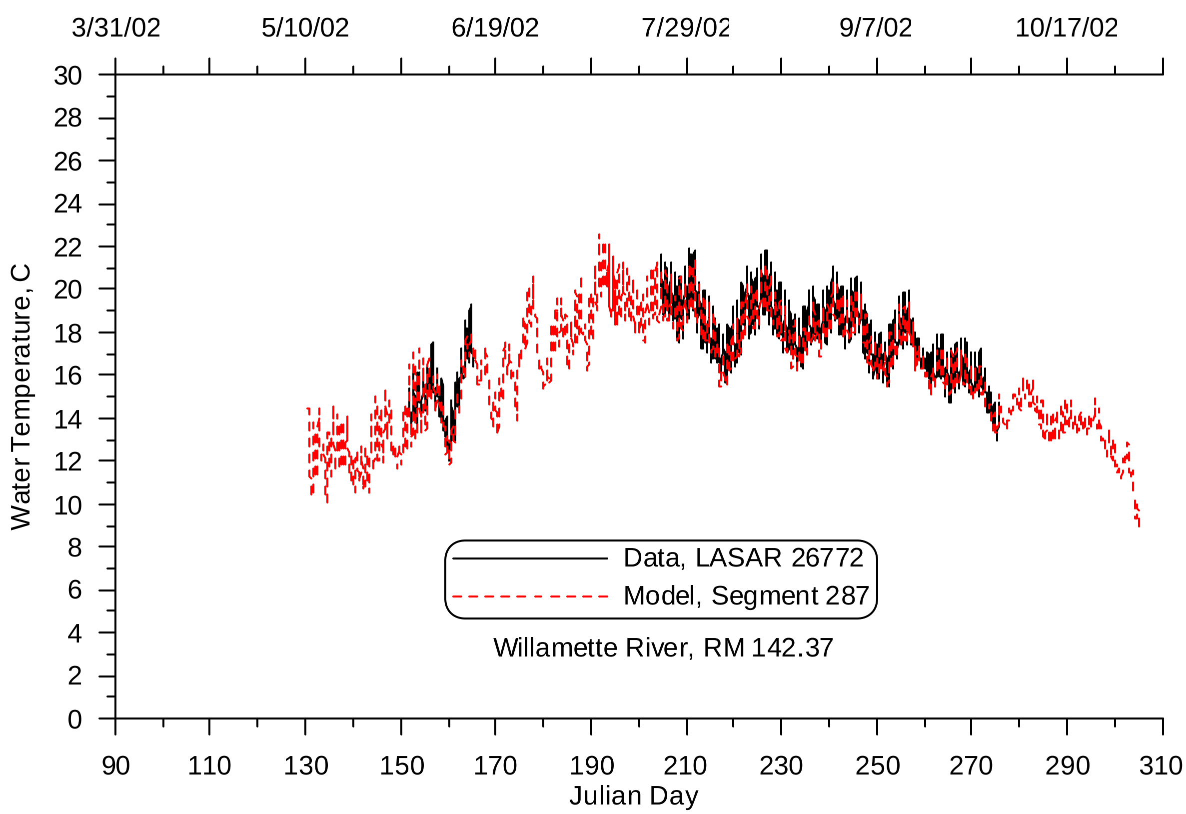

Figure 234: Upper Willamette River at RM 142.4 model-data continuous temperature comparison, 2002

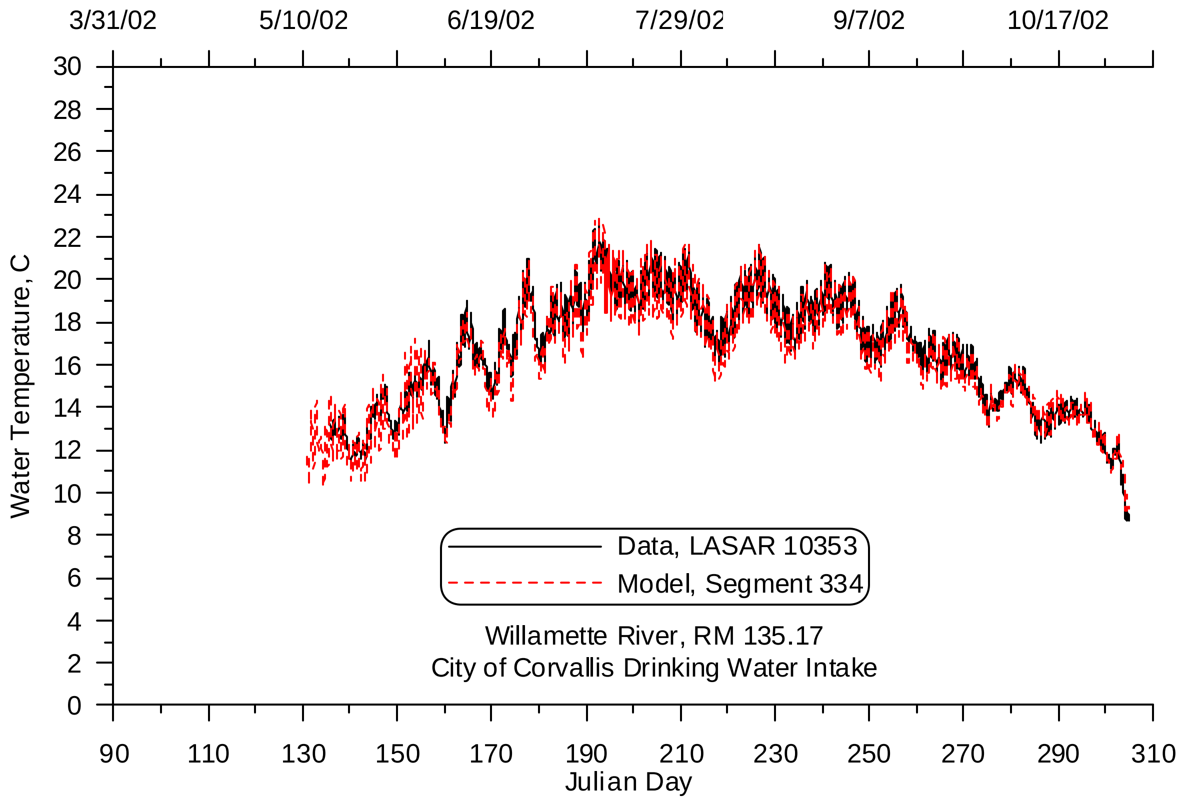

Figure 235: Upper Willamette River at Corvallis model-data continuous temperature comparison, 2002

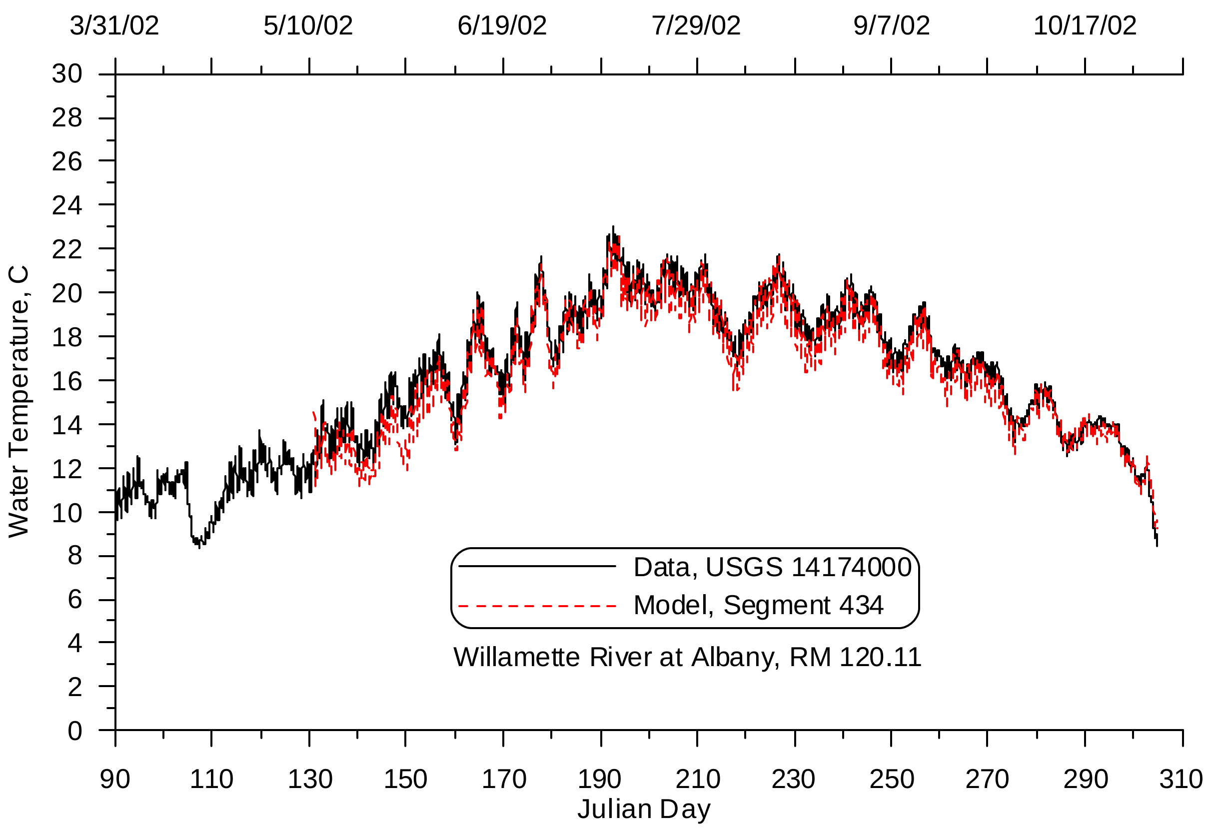

Figure 236: Upper Willamette River at Albany model-data continuous temperature comparison, 2002

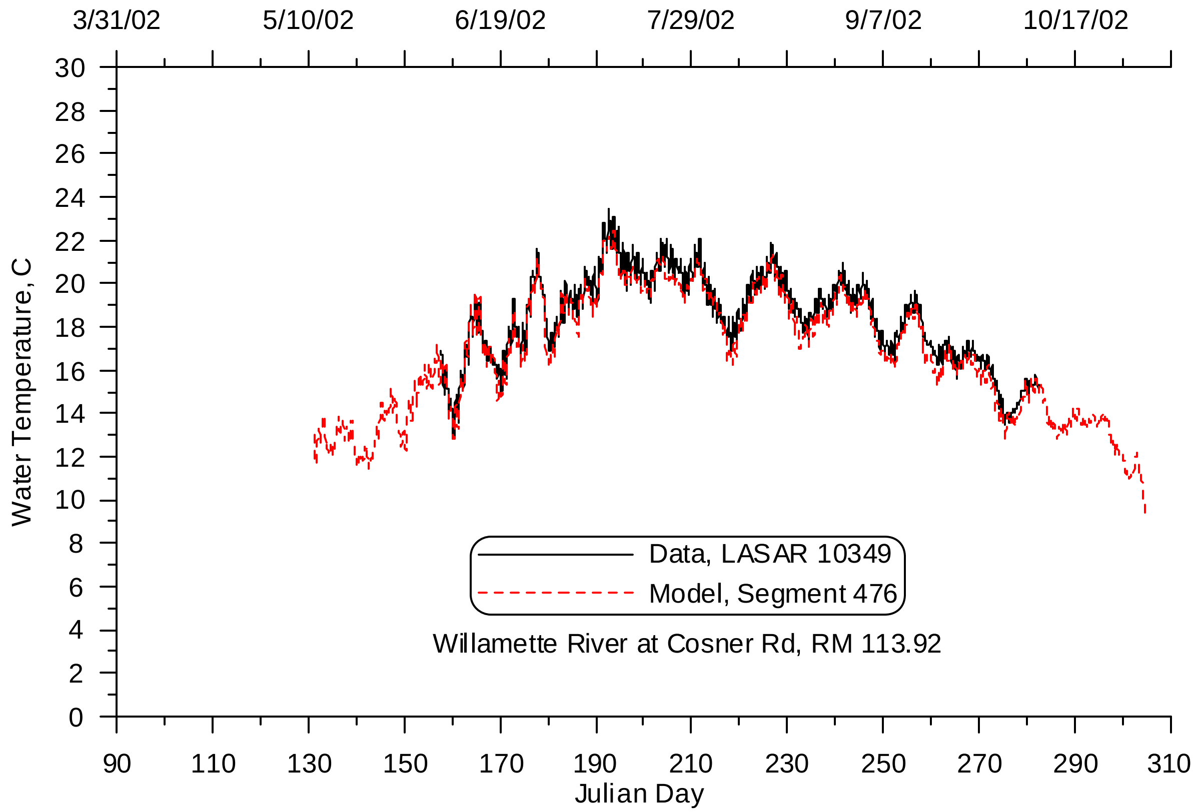

Figure 237: Upper Willamette River at Conser Rd model-data continuous temperature comparison, 2002

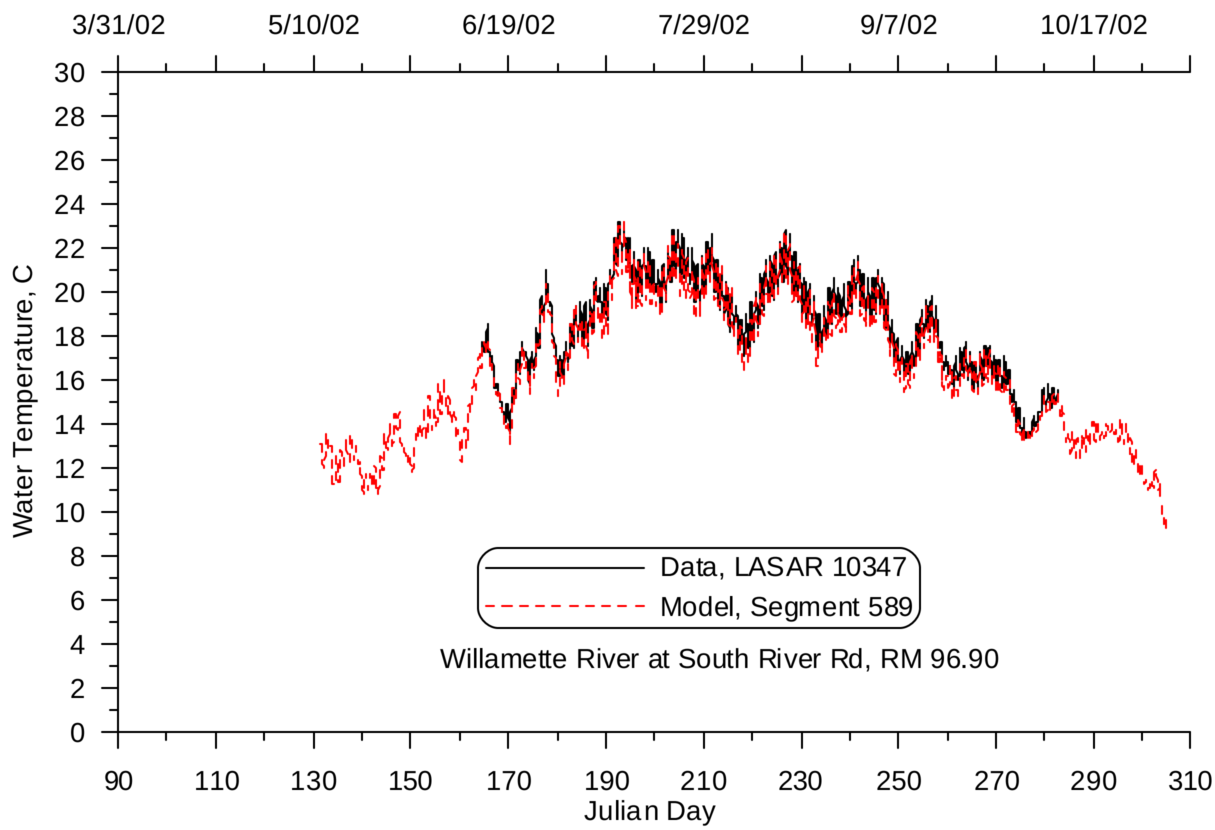

Figure 238: Upper Willamette River at South River Rd model-data continuous temperature comparison, 2002

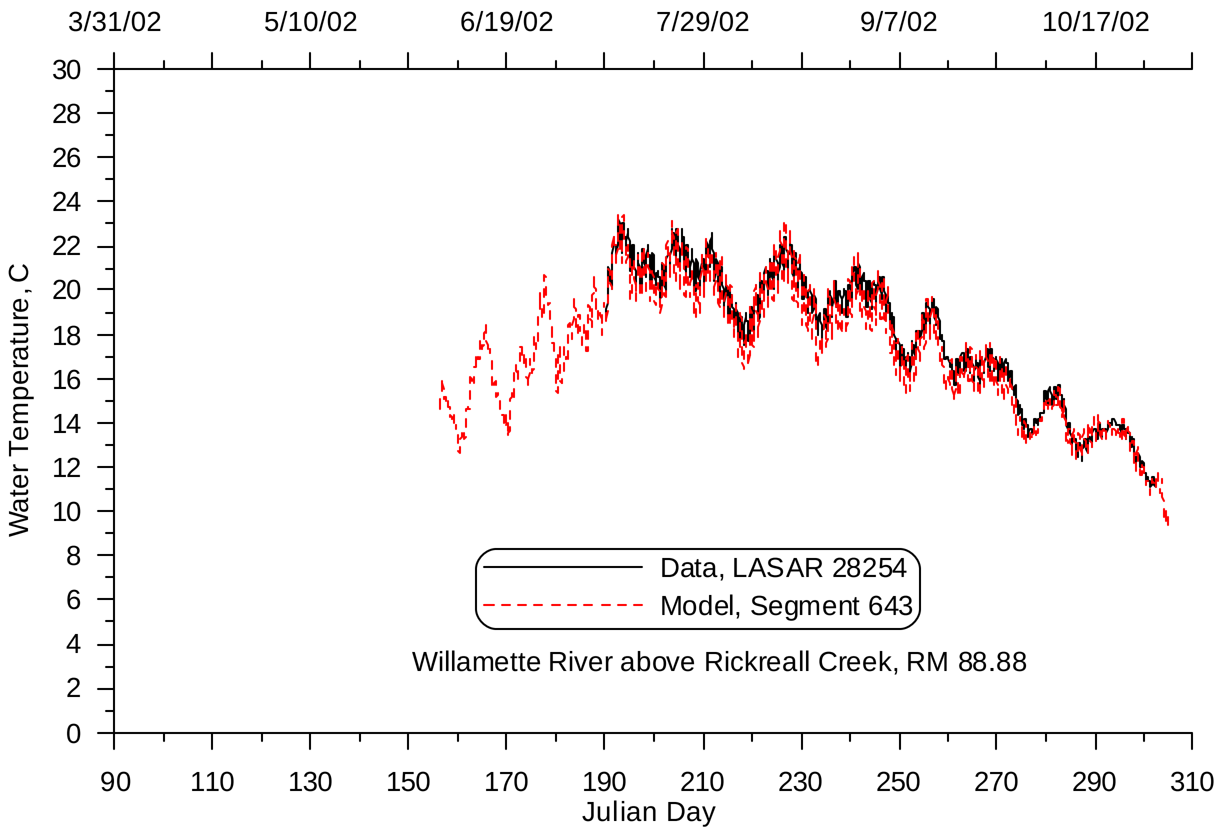

Figure 239: Upper Willamette River above Rickreall Creek model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

<u>Year 2001</u>

The daily maximum water temperature statistics for the 2001 model year are reported in Table 31. Statistics were calculated over the calibration period, (6/12/2001 to 9/25/01), excepting period of missing data. The RMS error for all sites was less than 1 °C, which indicates that the model is usually within 1 °C of the data. The values of the mean error range from –0.408 to 0.872 °C and indicate the range of the bias of the daily maximum temperature and show a slight warm bias in the peak daily temperature overall. The greater mean error in the daily maximum temperature than the mean temperature is a result of the model diurnal temperature variation often being larger than the data.

Table 31: Upper Willamette River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 10359	185.3	2	105	0.02	0.05	0.15
LASAR 28723	177.7	53	100	0.38	0.38	0.43
USGS 14166000	162.0	156	105	0.87	0.88	0.99
LASAR 26755	151.6	227	105	0.87	0.88	0.99
LASAR 26753	147.4	255	105	0.74	0.75	0.87

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 26772	142.4	287	105	0.40	0.45	0.57
LASAR 10353	135.2	334	105	-0.01	0.35	0.43
USGS 14174000	120.2	434	47	0.25	0.36	0.45
LASAR 10349	113.9	476	105	0.39	0.52	0.66
LASAR 10347	96.9	589	105	-0.42	0.50	0.60
LASAR 28254	88.9	643	105	0.32	0.60	0.81
USGS 14191000	84.7	666	25	0.36	0.55	0.69

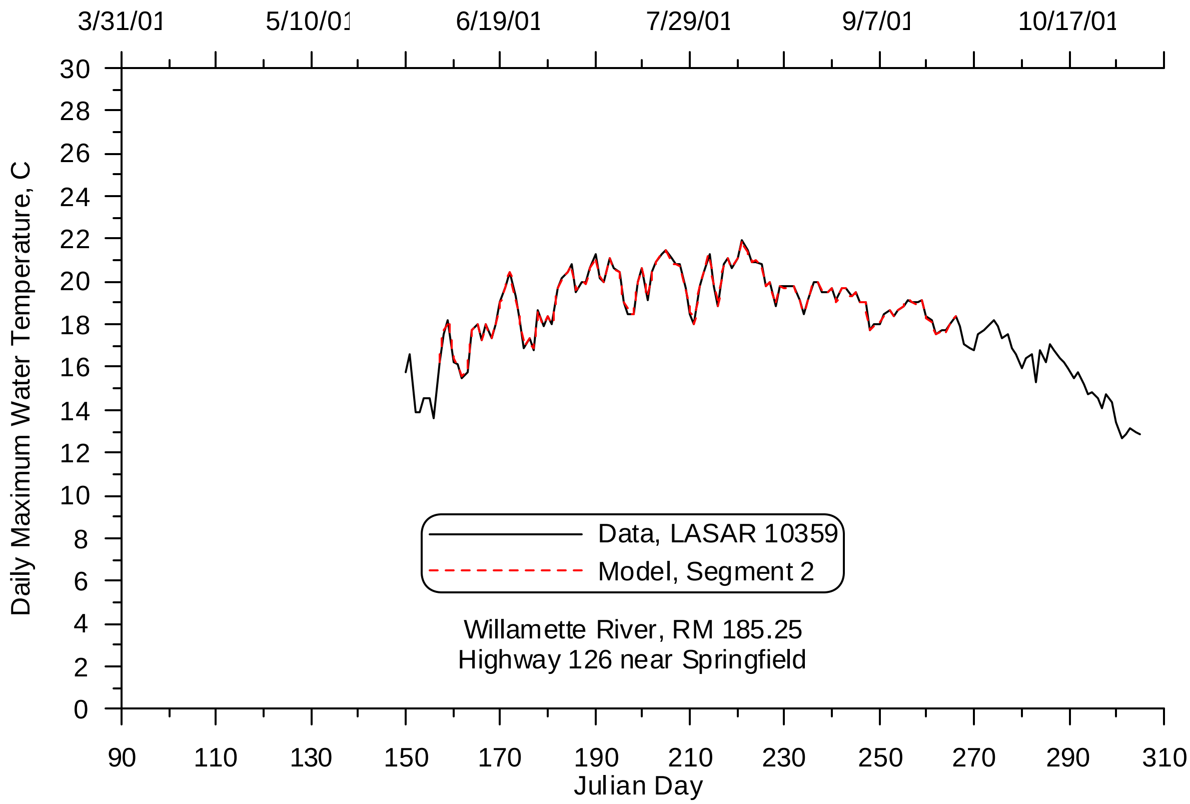

Figure 240: Upper Willamette River near Springfield model-data daily maximum temperature comparison, 2001

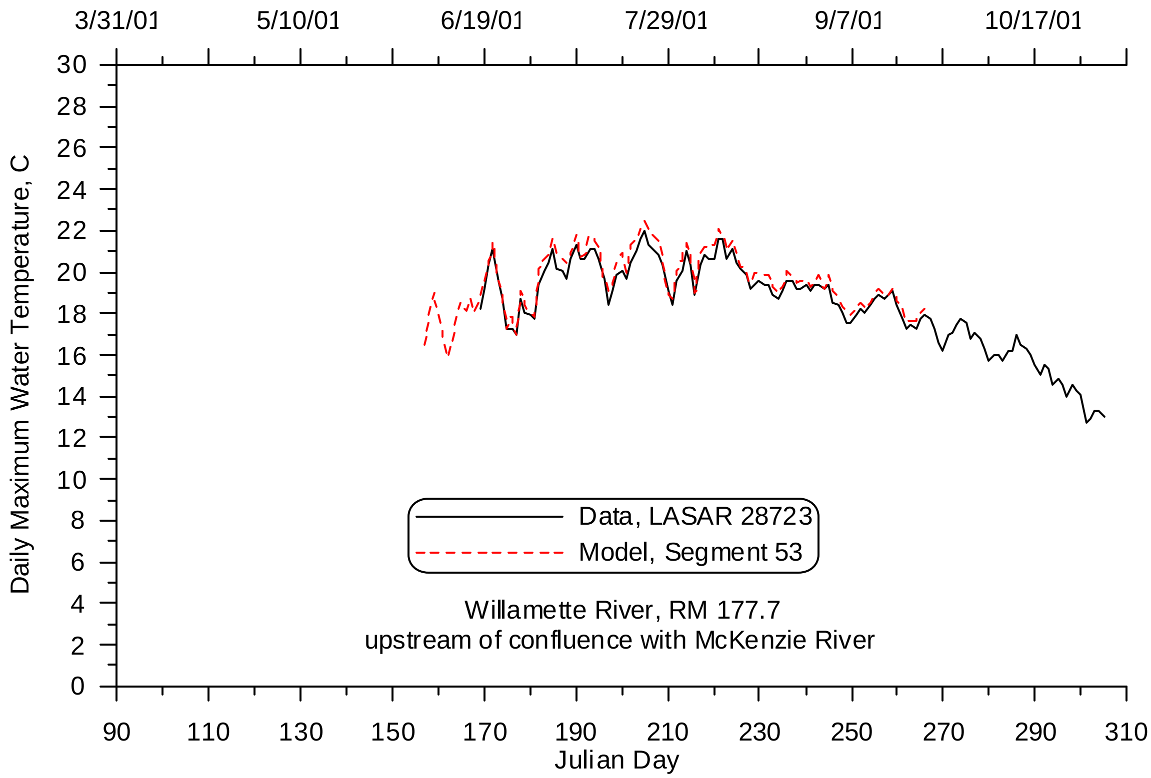

Figure 241: Upper Willamette River above McKenzie River model-data daily maximum temperature comparison, 2001

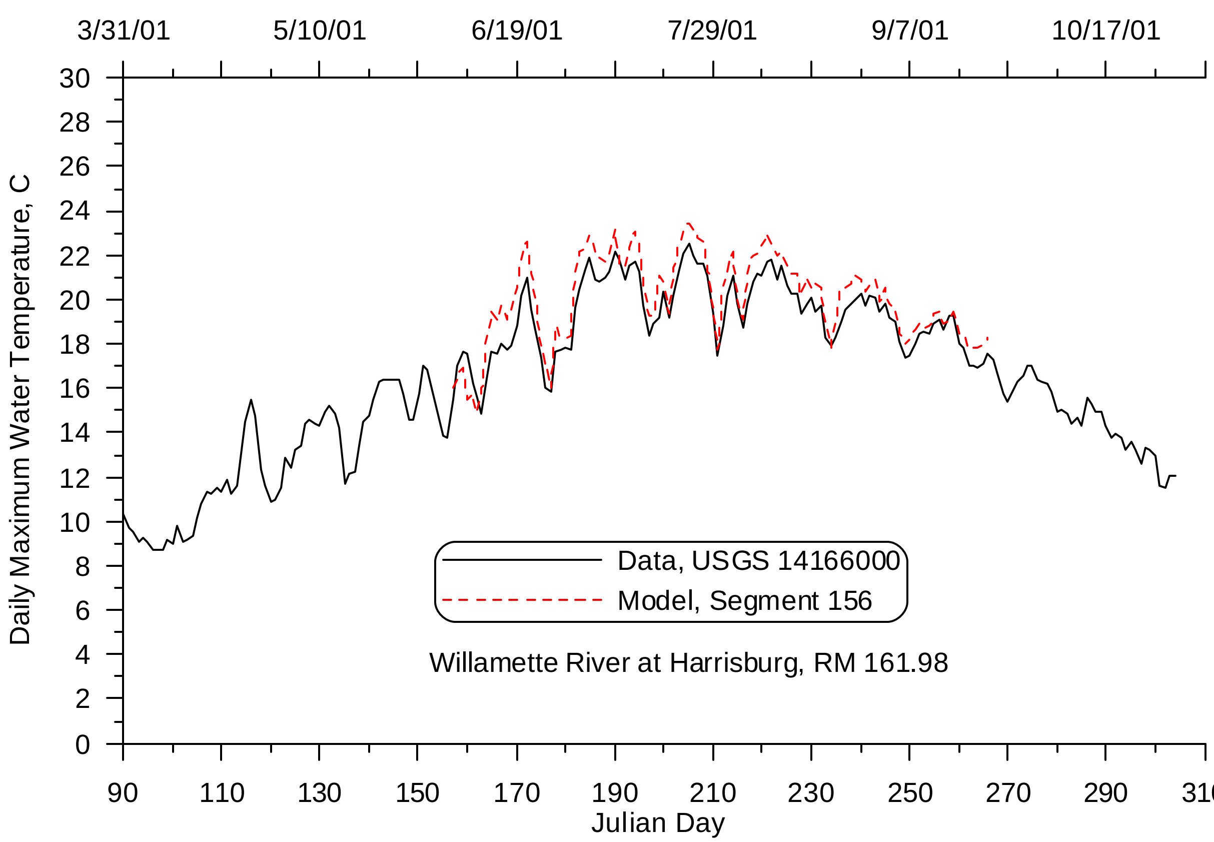

Figure 242: Upper Willamette River at Harrisburg model-data daily maximum temperature comparison, 2001

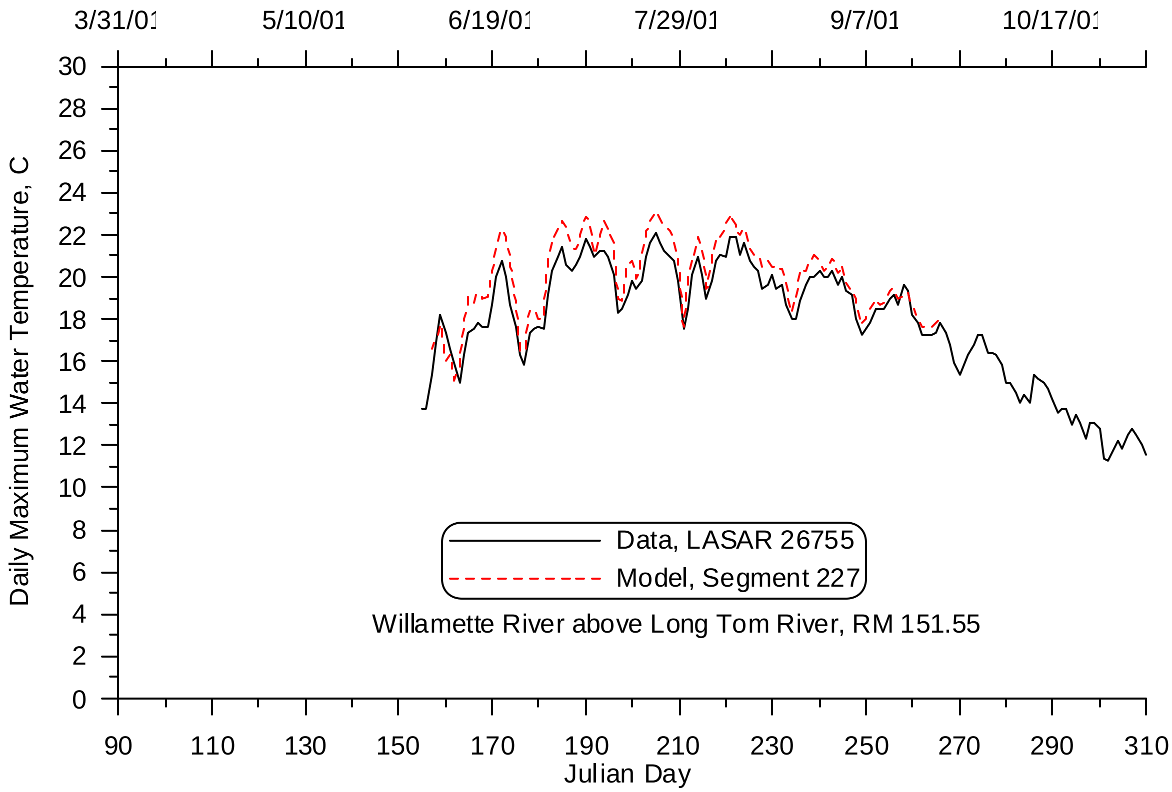

Figure 243: Upper Willamette River above Long Tom River model-data daily maximum temperature comparison, 2001

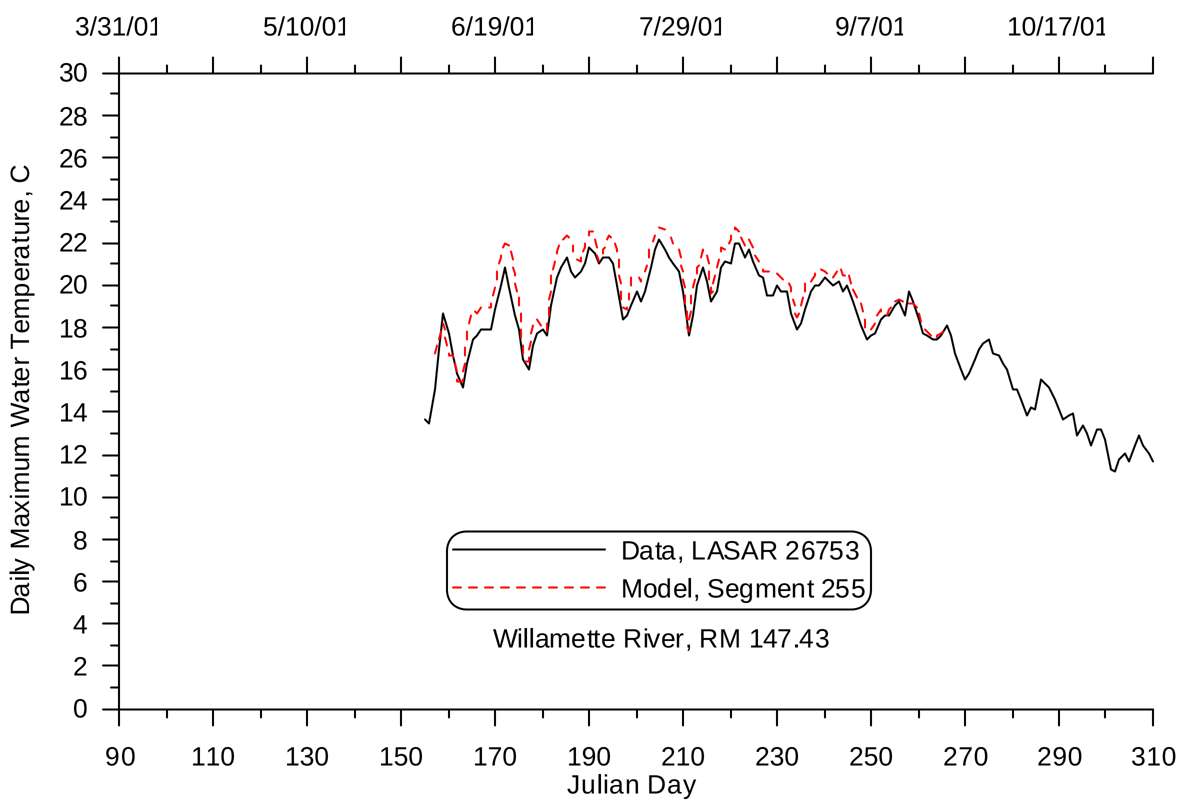

Figure 244: Upper Willamette River at RM 147.4 model-data daily maximum temperature comparison, 2001

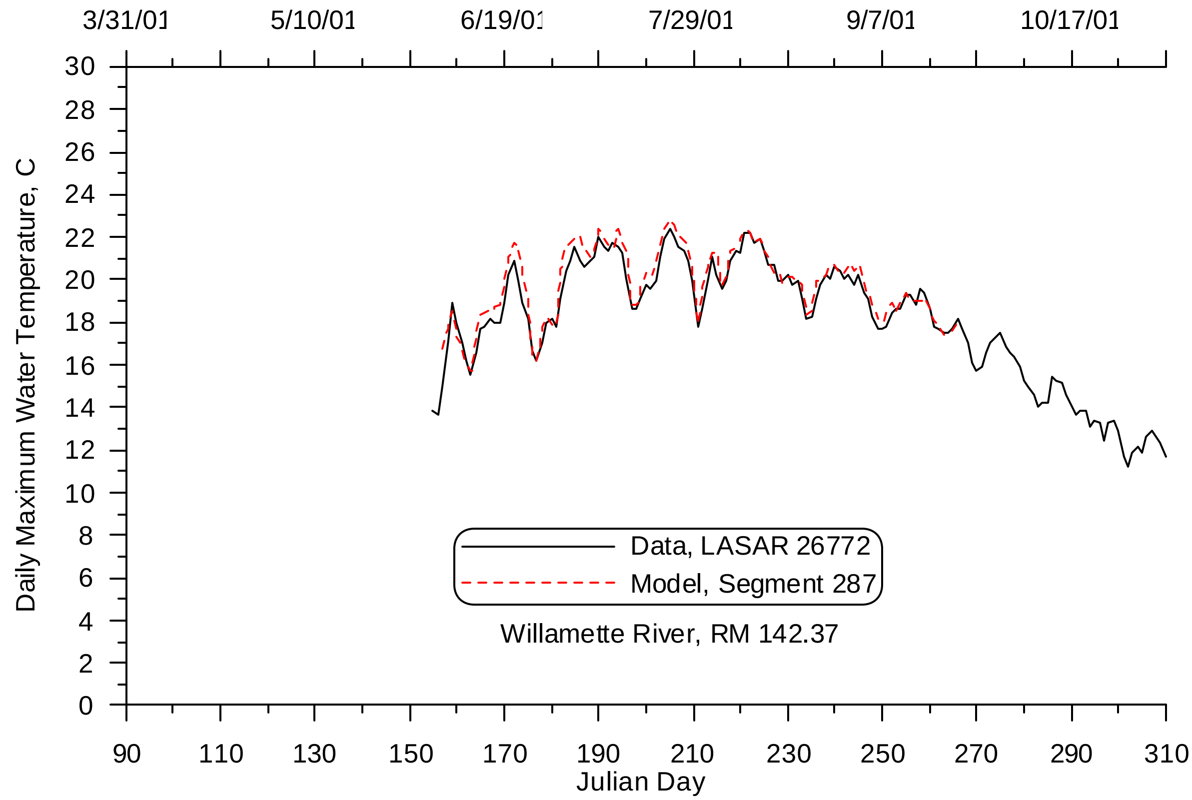

Figure 245: Upper Willamette River at RM 142.4 model-data daily maximum temperature comparison, 2001

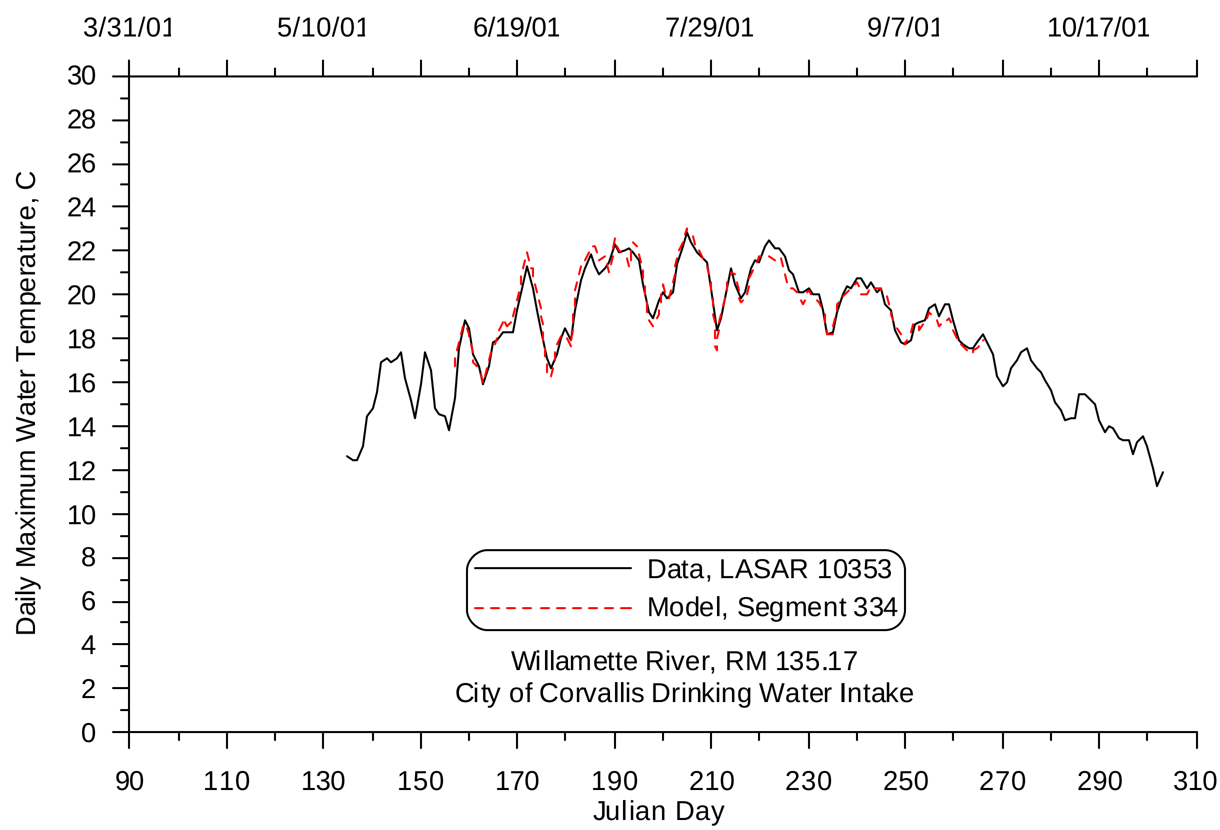

Figure 246: Upper Willamette River at Corvallis River model-data daily maximum temperature comparison, 2001

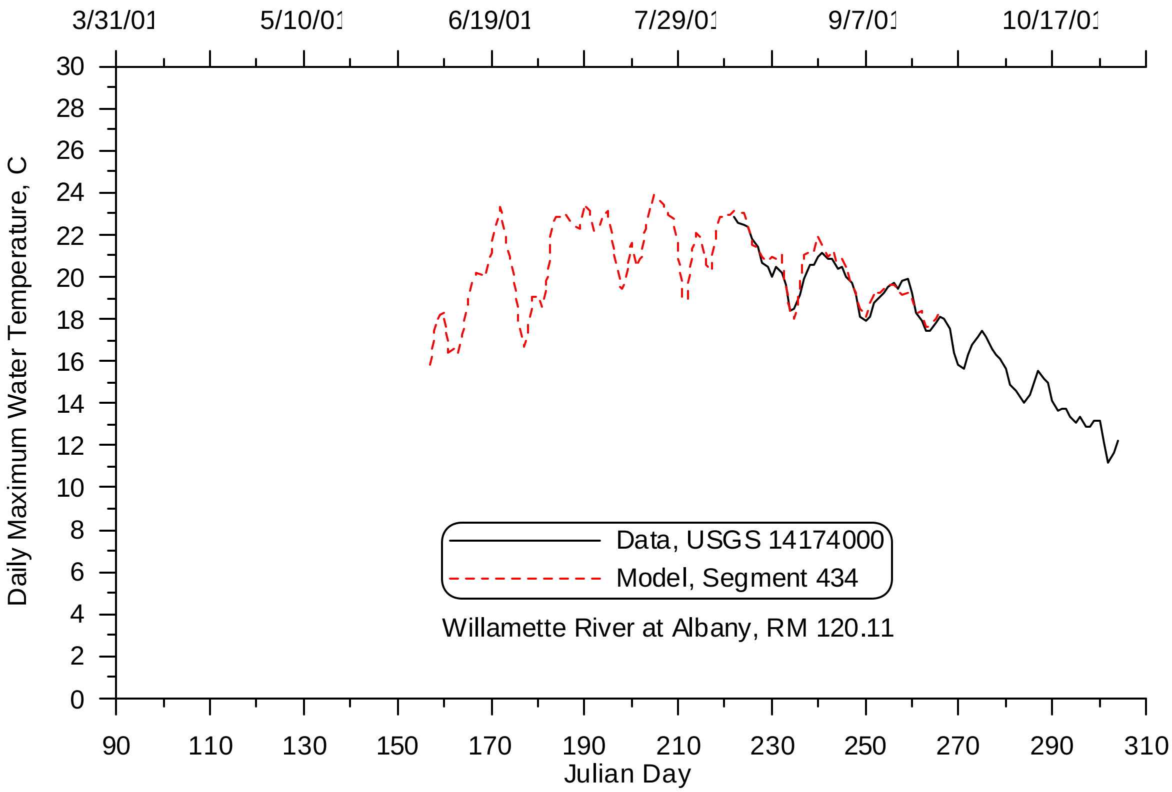

Figure 247: Upper Willamette River at Albany model-data daily maximum temperature comparison, 2001

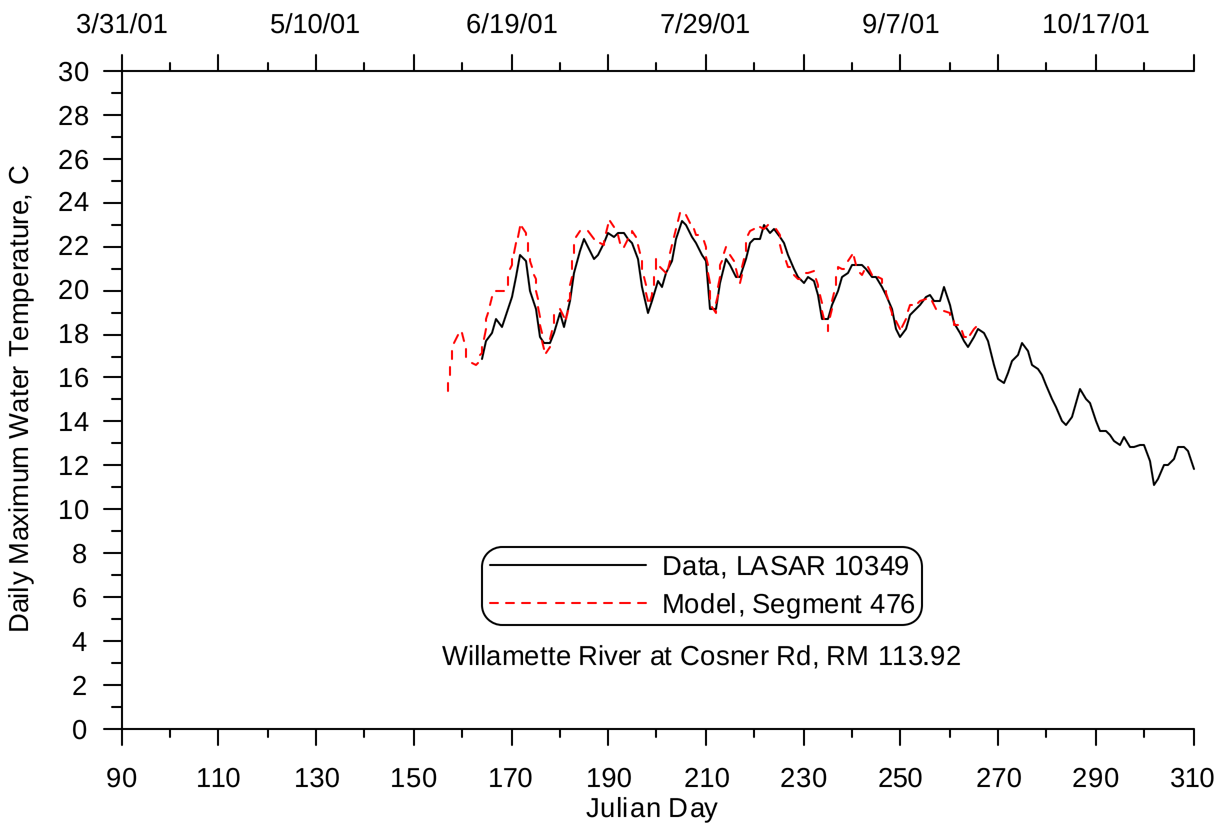

Figure 248: Upper Willamette River at Conser Rd model-data daily maximum temperature comparison, 2001

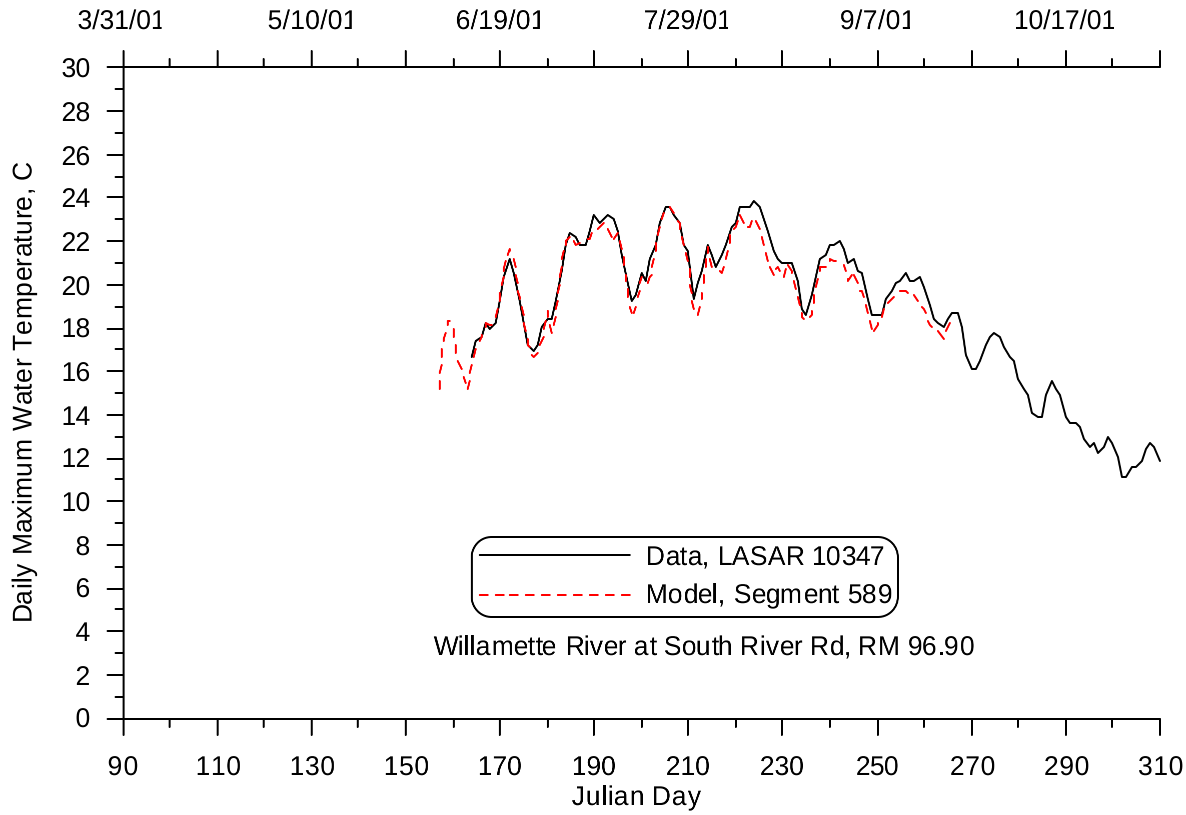

Figure 249: Upper Willamette River at South River Rd model-data daily maximum temperature comparison, 2001

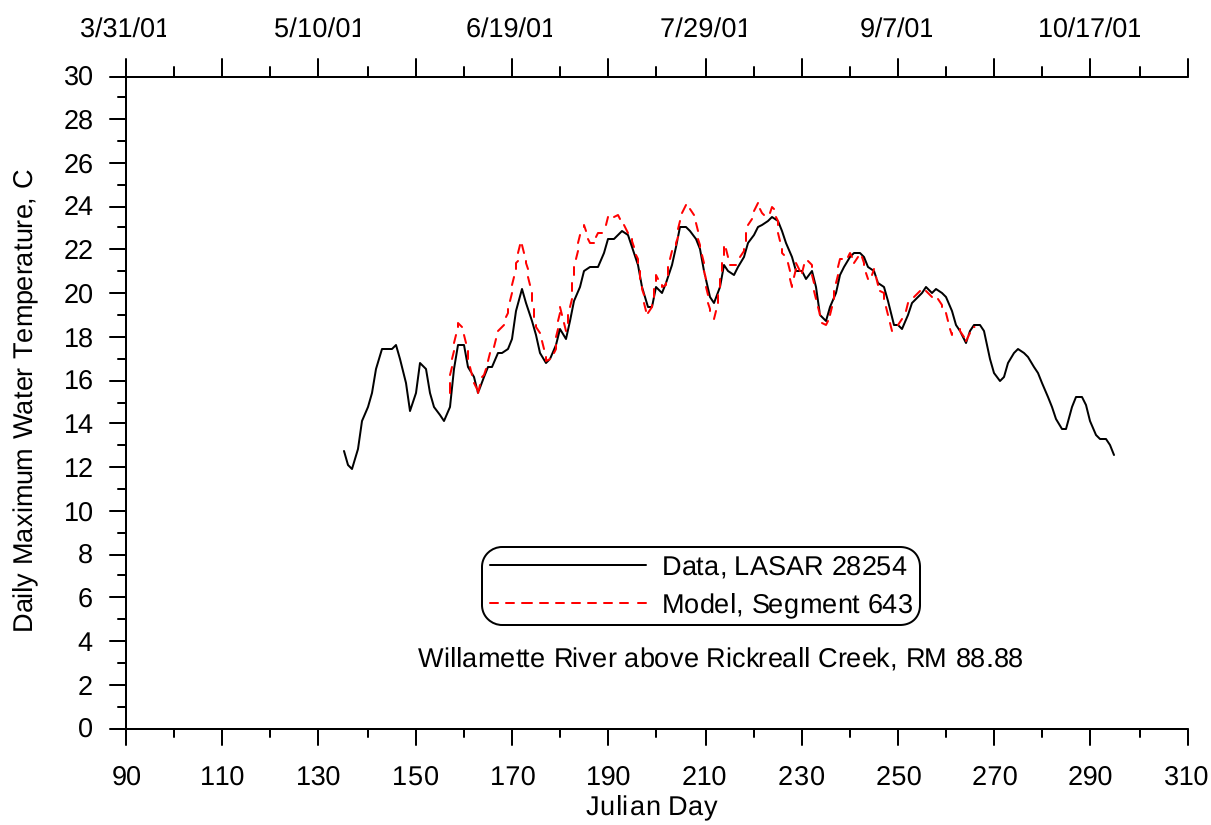

Figure 250: Upper Willamette River above Rickreall Creek model-data daily maximum temperature comparison, 2001

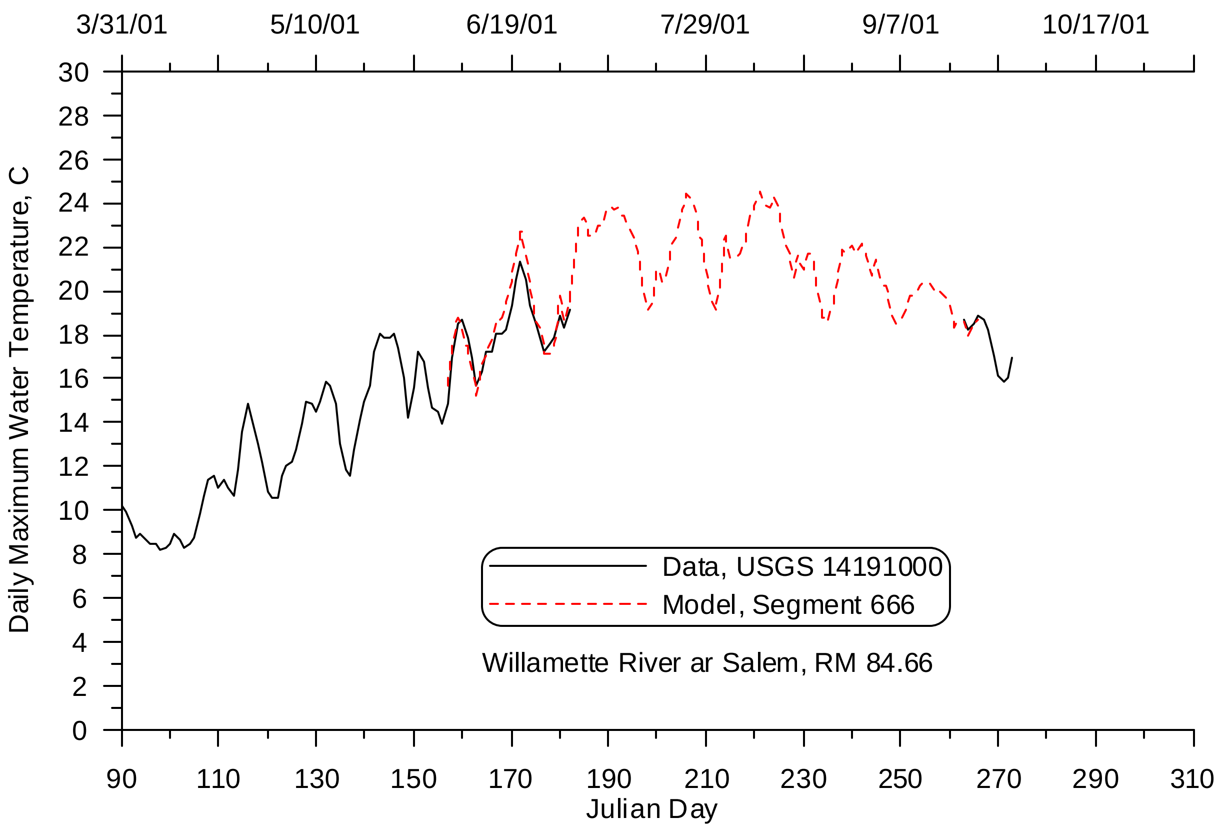

Figure 251: Upper Willamette River at Salem model-data daily maximum temperature comparison, 2001

Year 2002

The daily maximum water temperature statistics for the 2002 model year are reported in Table 32. Statistics were calculated over the calibration period, (6/4/2002 to 10/1/02), excepting period of missing data. The RMS error for all sites was less than 0.7 °C, which indicates that the model is usually within 0.7 °C of the data. The values of the mean error range from –0.63 to 0.33 °C and indicate the range of the bias of the daily maximum temperature. The daily maximum water temperature for the 2002 model has a slight cold bias in contrast to the 2001 model which has a slight warm bias.

Table 32: Upper Willamette River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 10359	185.3	2	118	0.00	0.03	0.05
LASAR 28723	177.7	53	120	0.33	0.39	0.44
USGS 14166000	162.0	156	120	-0.26	0.30	0.38
LASAR 26755	151.6	227	119	-0.56	0.59	0.65
LASAR 26753	147.4	255	119	-0.38	0.43	0.50
LASAR 26772	142.4	287	81	-0.63	0.63	0.70
LASAR 10353	135.2	334	120	-0.10	0.28	0.37
USGS 14174000	120.2	434	120	-0.34	0.37	0.45

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 10349	113.9	476	119	-0.51	0.53	0.61
LASAR 10347	96.9	589	112	-0.36	0.39	0.48
LASAR 28254	88.9	643	86	-0.13	0.36	0.49

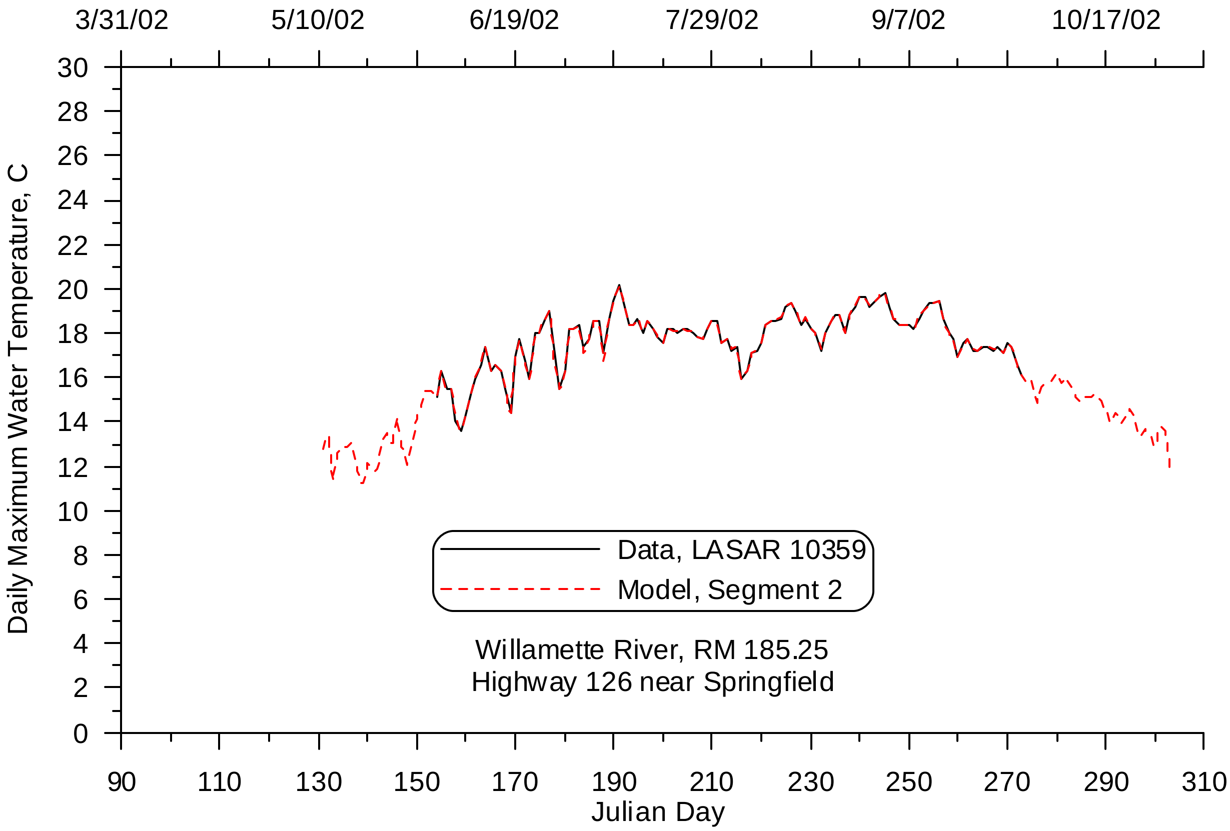

Figure 252: Upper Willamette River near Springfield model-data daily maximum temperature comparison, 2002

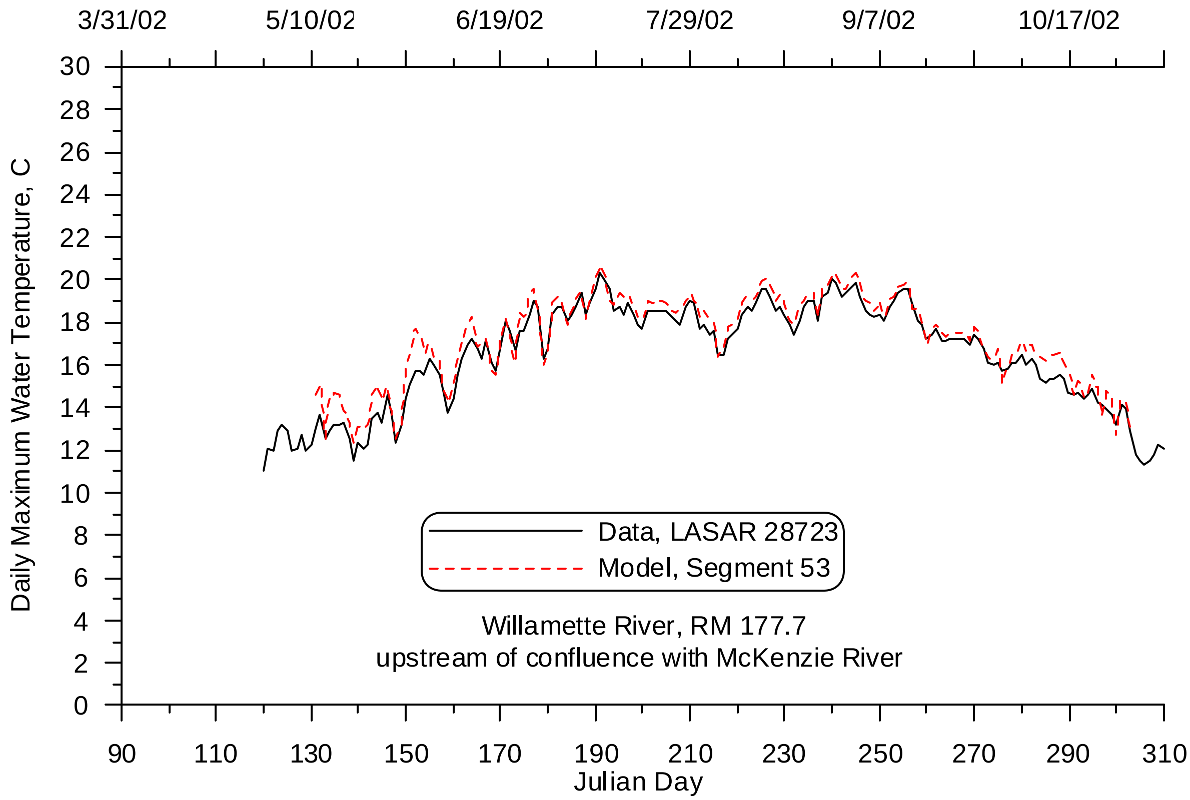

Figure 253: Upper Willamette River above McKenzie River model-data daily maximum temperature comparison, 2002

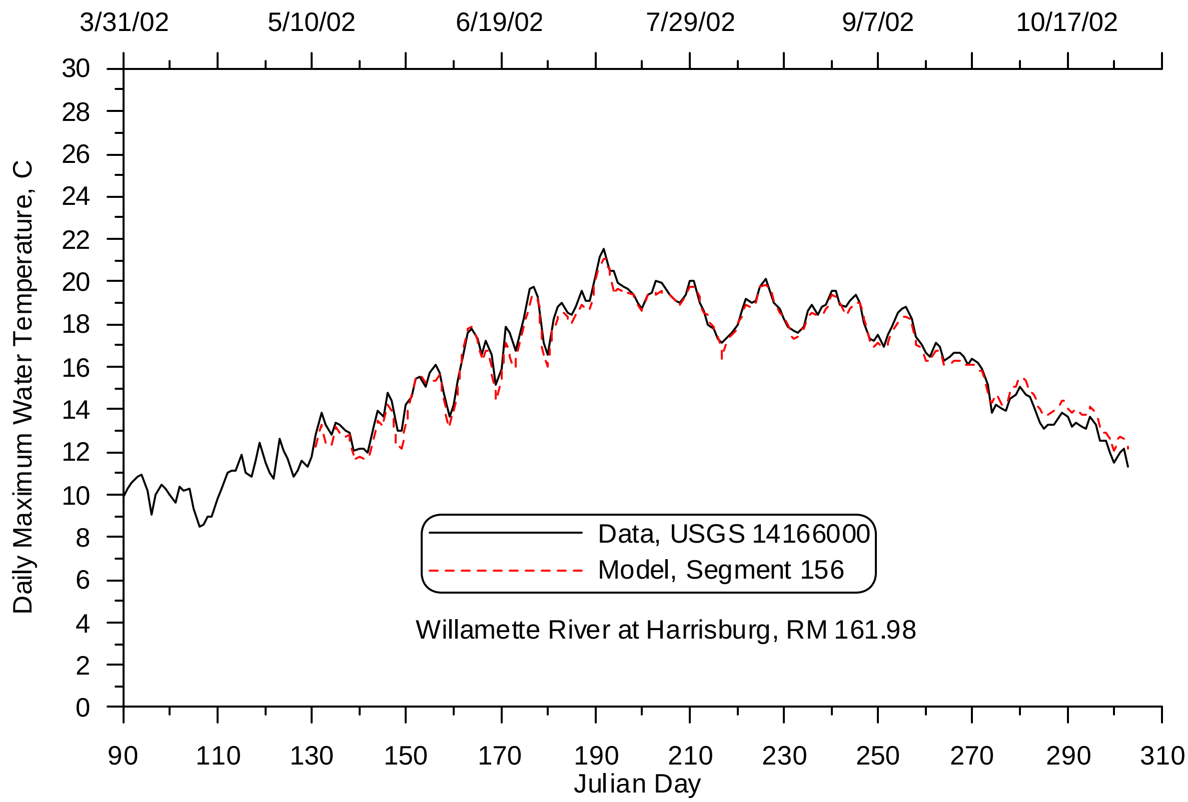

Figure 254: Upper Willamette River at Harrisburg model-data daily maximum temperature comparison, 2002

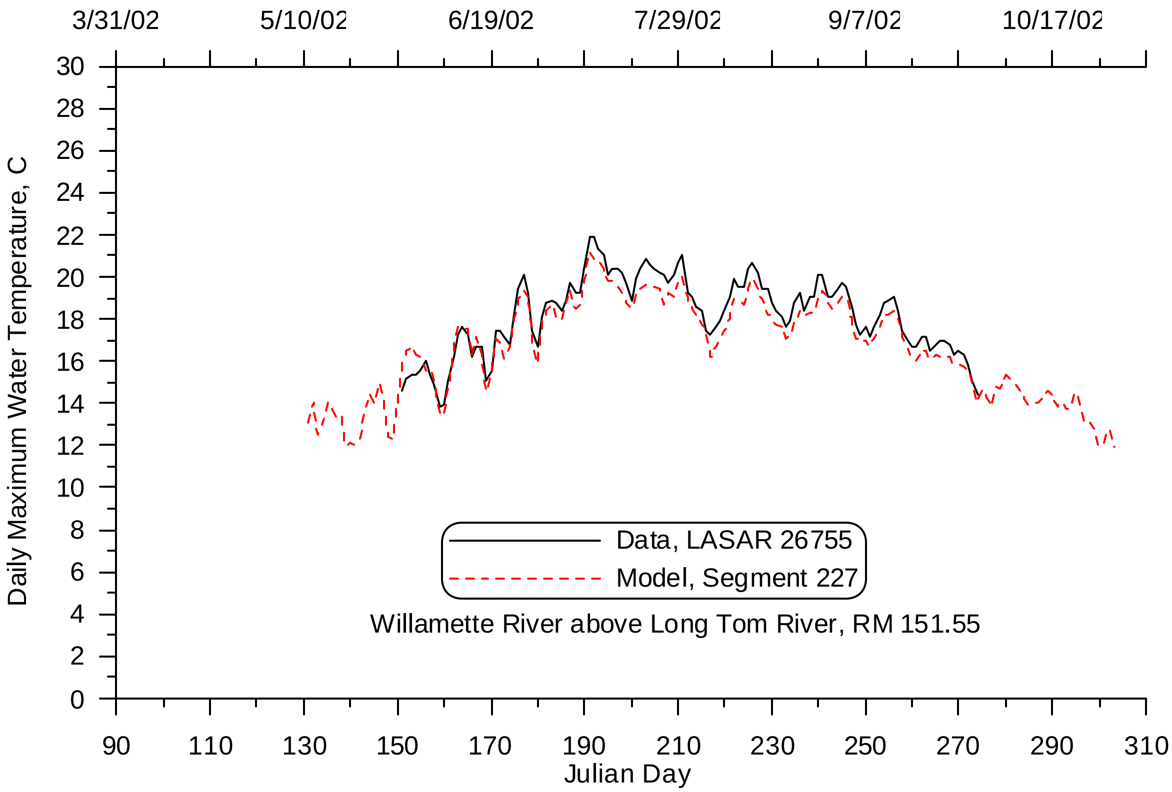

Figure 255: Upper Willamette River above Long Tom River model-data daily maximum temperature comparison, 2002

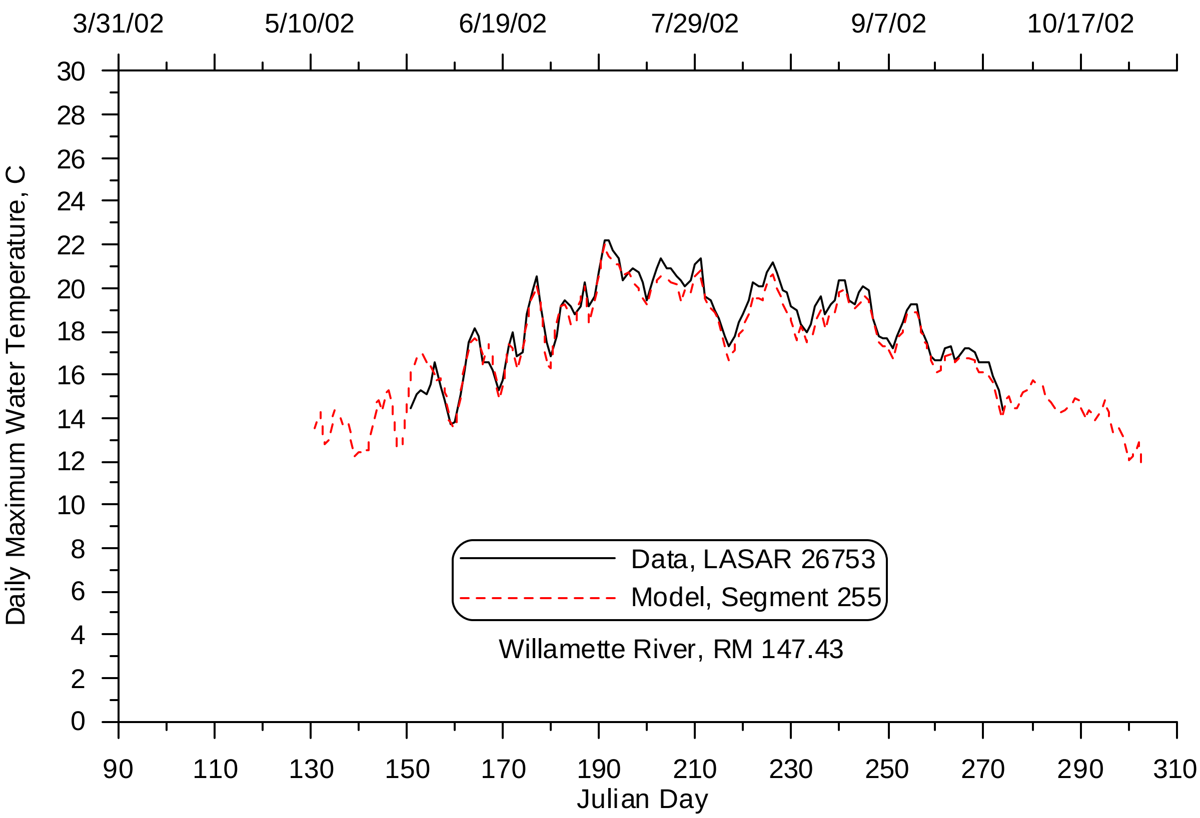

Figure 256: Upper Willamette River at RM 147.4 model-data daily maximum temperature comparison, 2002

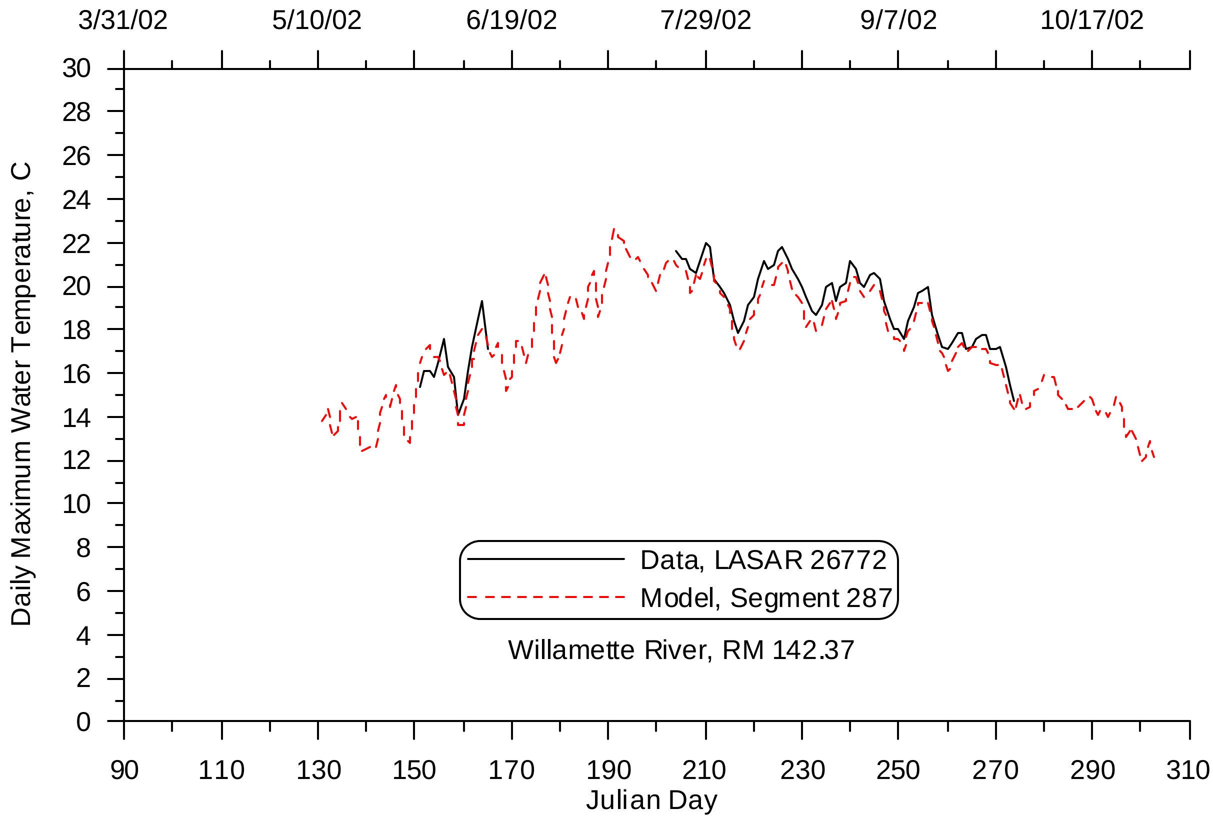

Figure 257: Upper Willamette River at RM 142.4 model-data daily maximum temperature comparison, 2002

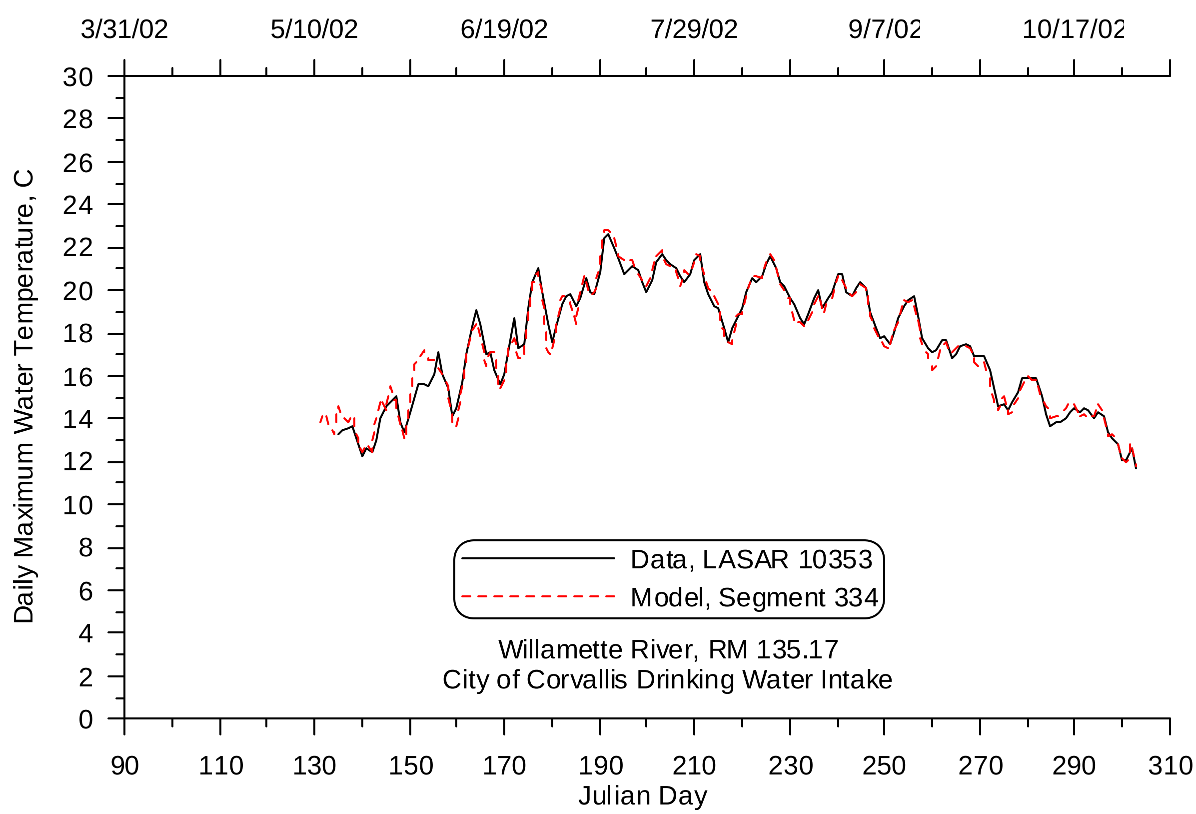

Figure 258: Upper Willamette River at Corvallis model-data daily maximum temperature comparison, 2002

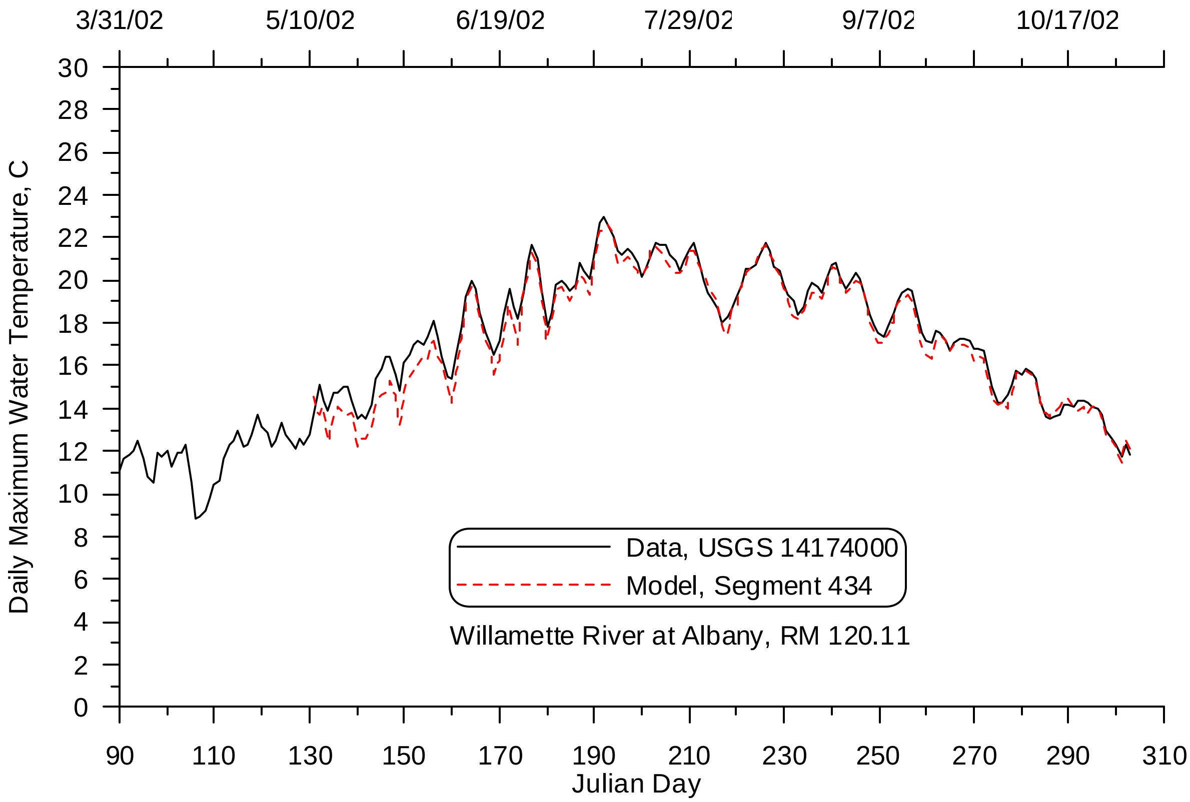

Figure 259: Upper Willamette River at Albany model-data daily maximum temperature comparison, 2002

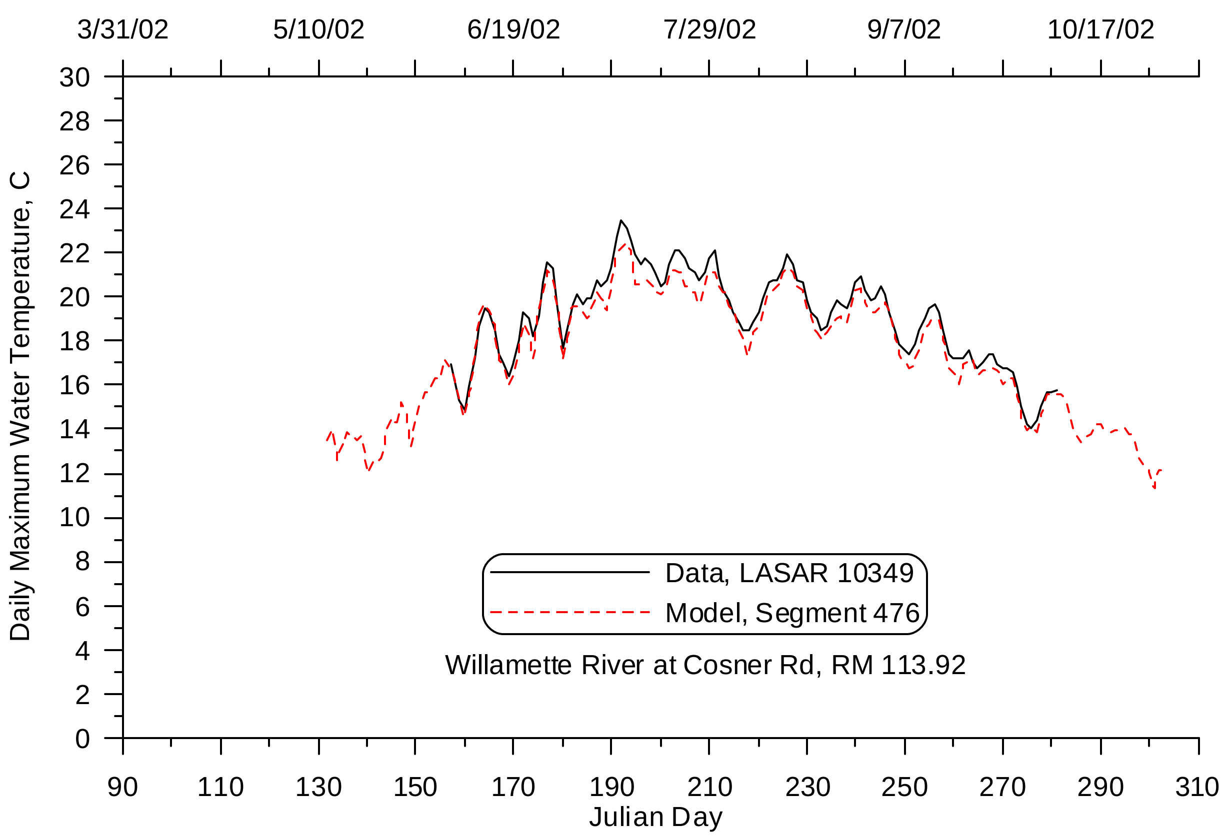

Figure 260: Upper Willamette River at Conser Rd model-data daily maximum temperature comparison, 2002

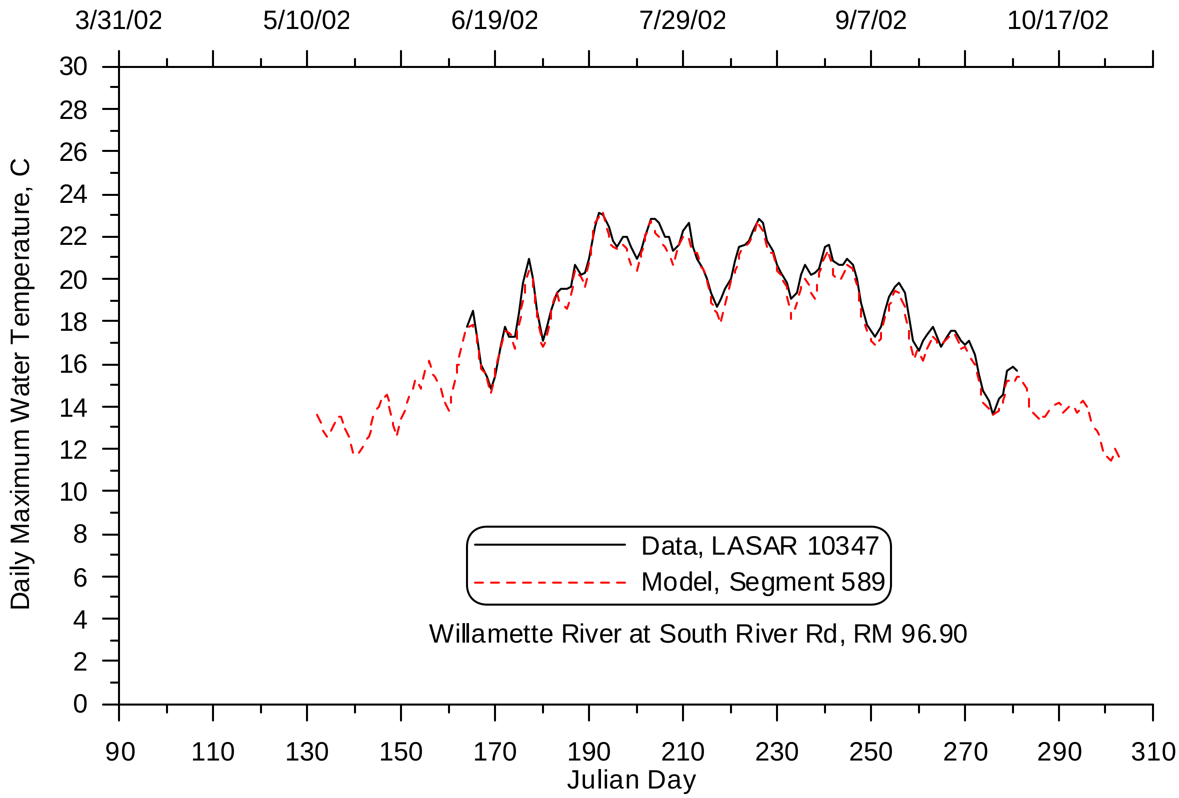

Figure 261: Upper Willamette River at South River Rd model-data daily maximum temperature comparison, 2002

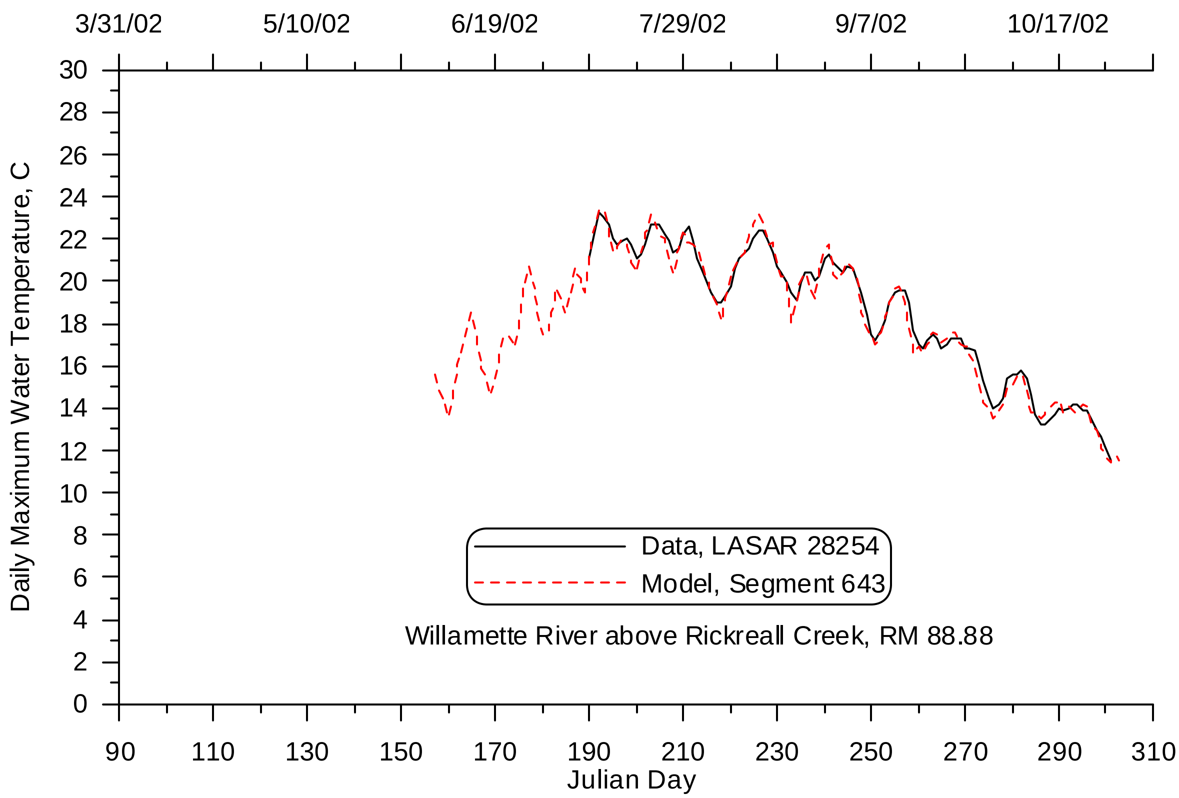

Figure 262: Upper Willamette River above Rickreall Creek model-data daily maximum temperature comparison, 2002

Clackamas River

Introduction

The Clackamas River model calibration was performed in a series of steps. Hydrodynamics, or water level and flow rates, were calibrated first, followed by channel widths and then temperature. Figure 263 shows the model domain from Rivermill Reservoir (RM 22.6) downstream to the river's confluence with the Lower Willamette River. The model calibration period for 2001 was from April 1 to September 30 and for 2002 from April 1 to October 1.

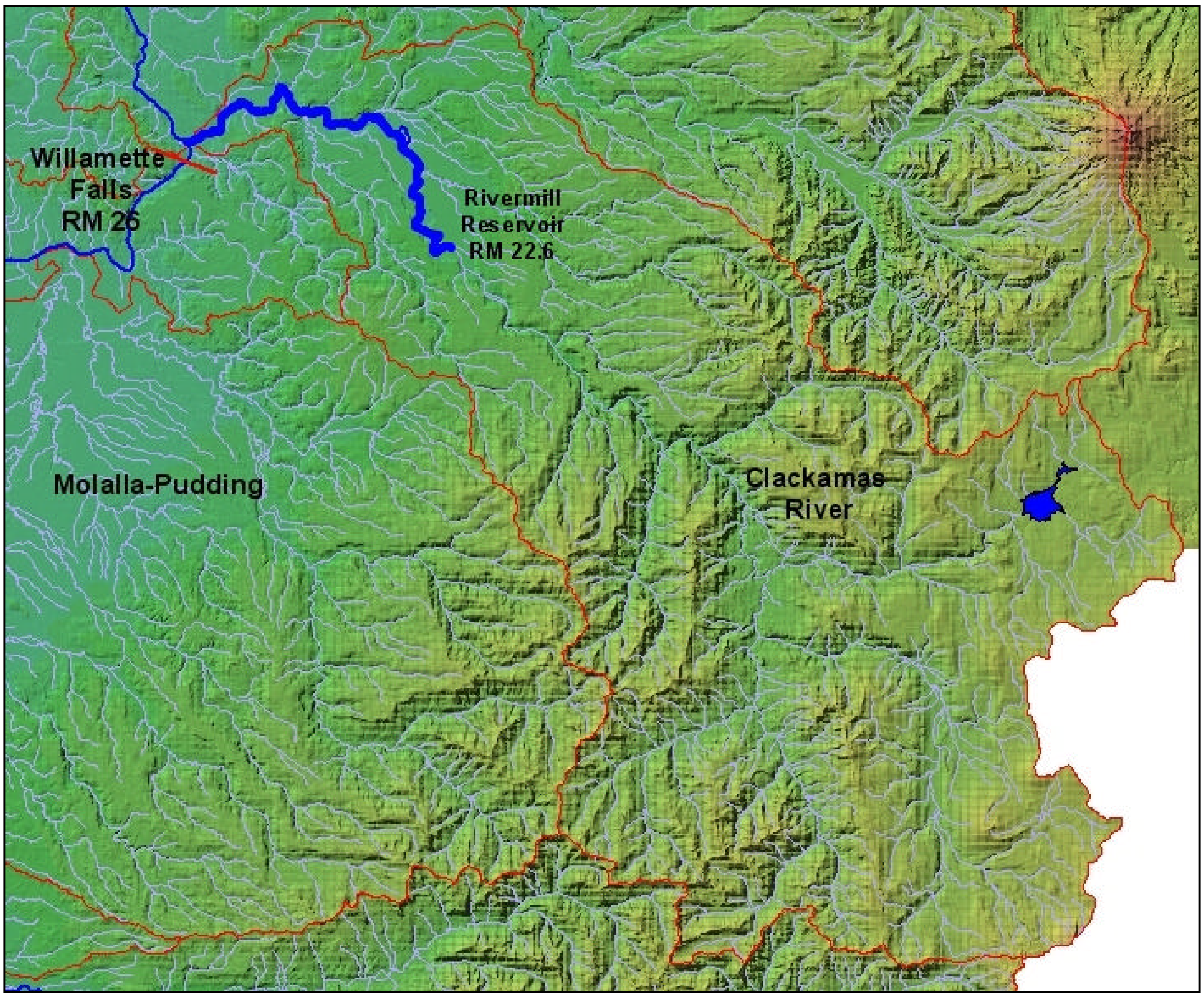

Figure 263: Clackamas River model region

Hydrodynamics

Hydrodynamics were calibrated using water level and flow data. The only calibration parameters used were Manning's friction factor, adjustments to the channel slope and the channel widths.

Flow and Water Surface Elevation

The Lower Clackamas River has two gage stations with continuous flow and water surface elevation data for calibrating the model. Figure 264 shows a map of the basin with the gage site locations and Table 33 shows a list of the gage sites with RM and corresponding model segment.

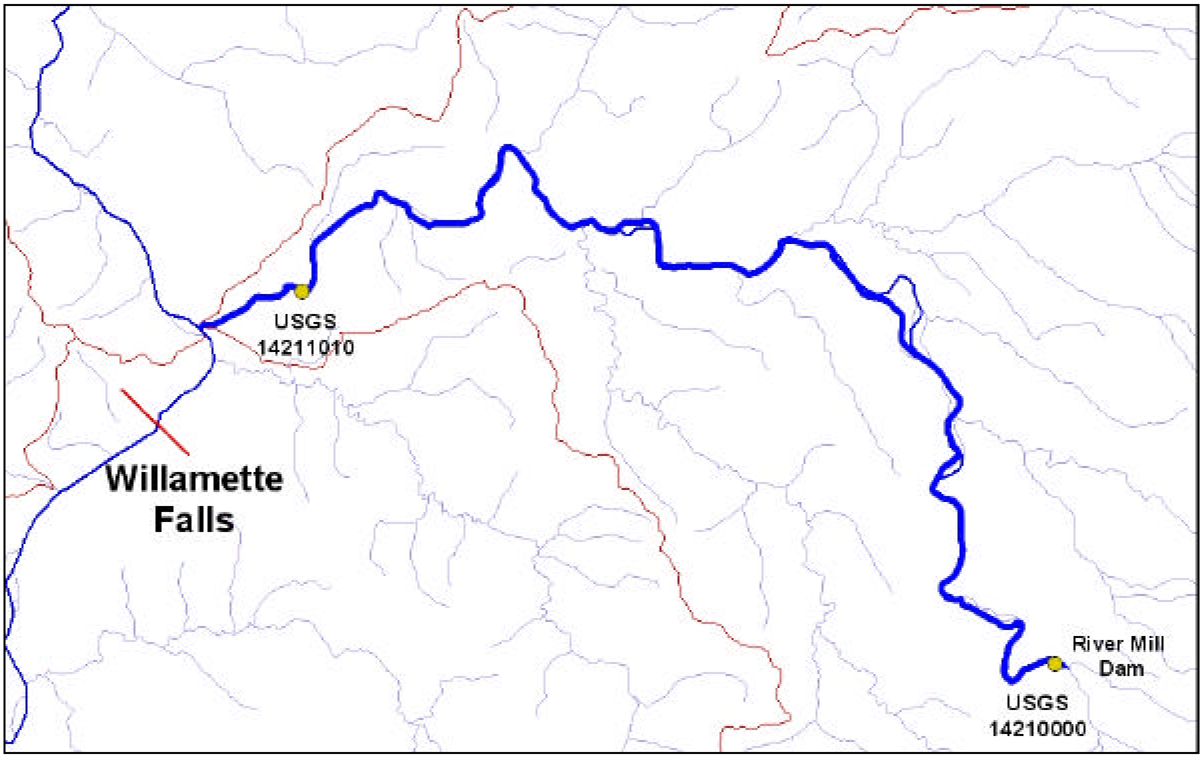

Figure 264: Clackamas River hydrodynamics calibration site locations

Table 33: Clackamas River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14210000	Clackamas River at Estacada, downstream of Rivermill Dam	22.22	2	Q & WL
USGS 14211010	Clackamas River near Oregon City	2.41	133	Q & WL

<u>Year 2001</u>

The hydrodynamics calibration was conducted from April to September in 2001 for both flow and water level. Table 34 lists the model-data error statistics for both flow and water level. Figure 265 through Figure 268 compare model predicted water level and flow with data. The figures indicate the model is capturing the appropriate amount of water over time in the river at both locations by simulating the short duration flow peaks. The water level predications match well with data and less so during the spring high flow period. The hydrodynamics were calibrated by adjusting Manning's friction factor and adjusting segment widths in the vicinity of the gaging stations. Manning's n had values of 0.12 in the upstream segments of the river and values of 0.06 in the lower reaches.

Table 34: Clackamas River hydrodynamic calibration model-data error statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14210000	22.22	2	8664	0.05	0.42	0.97
USGS 14211010	2.41	133	5380	0.01	1.38	2.42
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14210000	22.22	2	8664	0.23	0.23	0.34
USGS 14211010	2.41	133	5380	-0.02	0.05	0.07

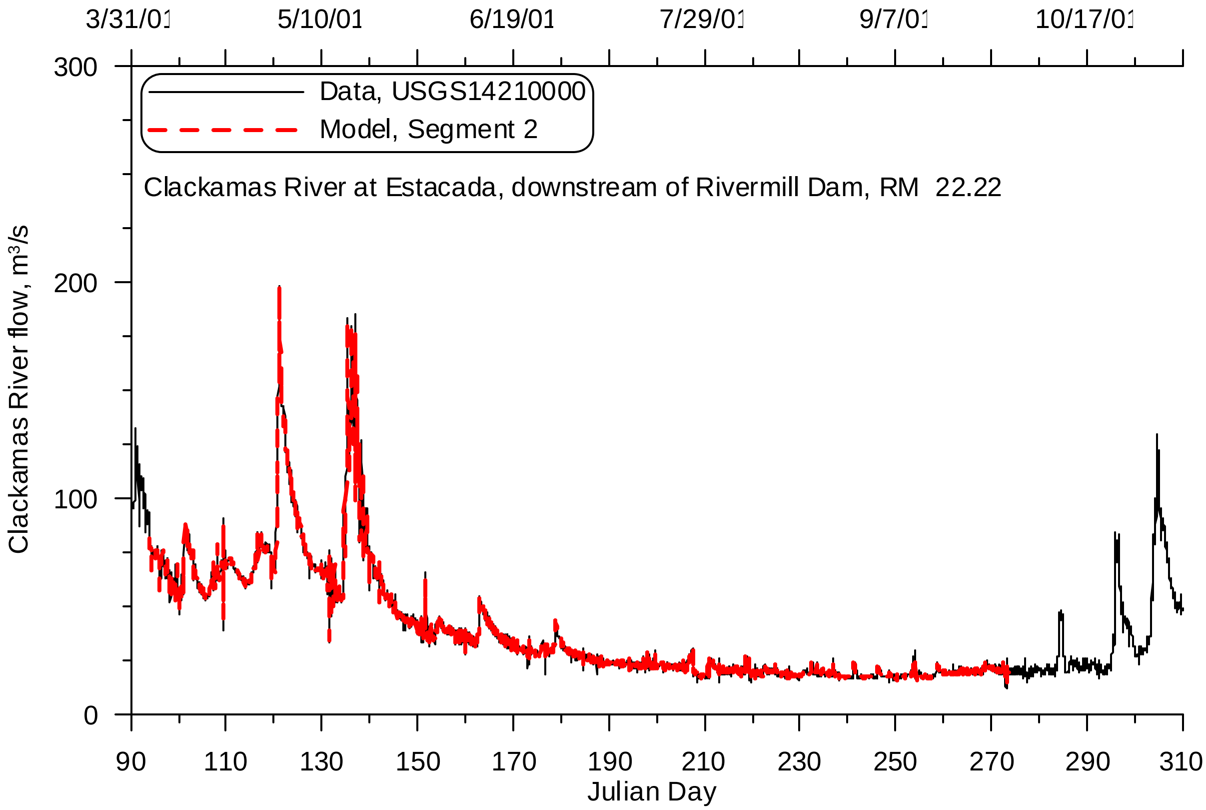

Figure 265: Clackamas River at Estacada model-data flow comparison, 2001

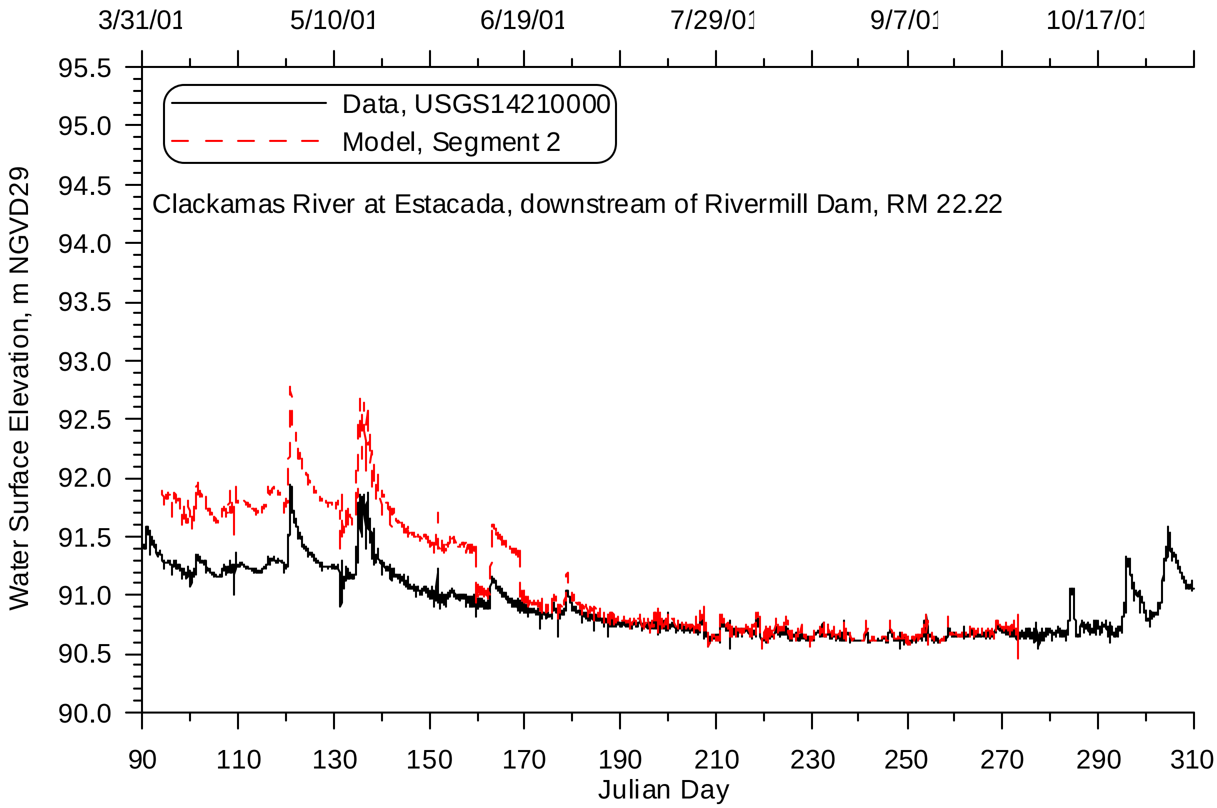

Figure 266: Clackamas River at Estacada model-data water level comparison, 2001

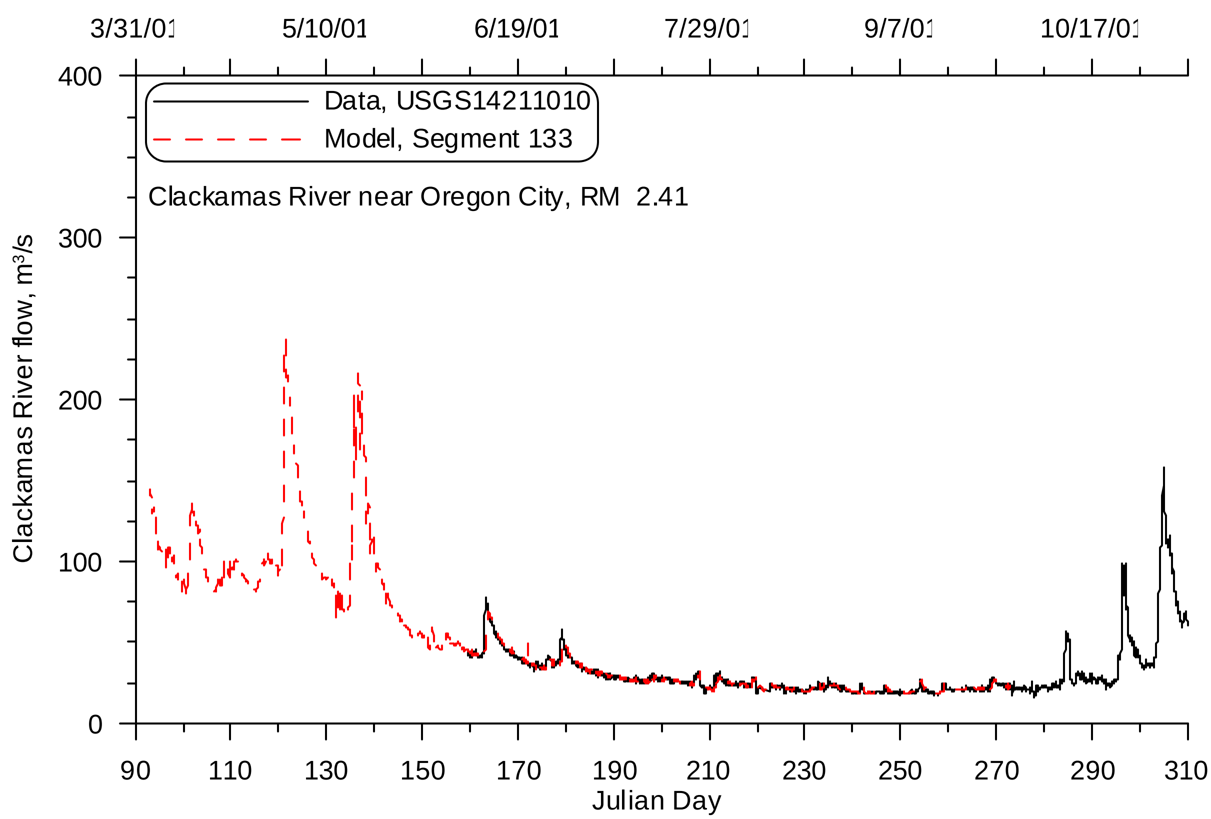

Figure 267: Clackamas River near Oregon City model-data flow comparison, 2001

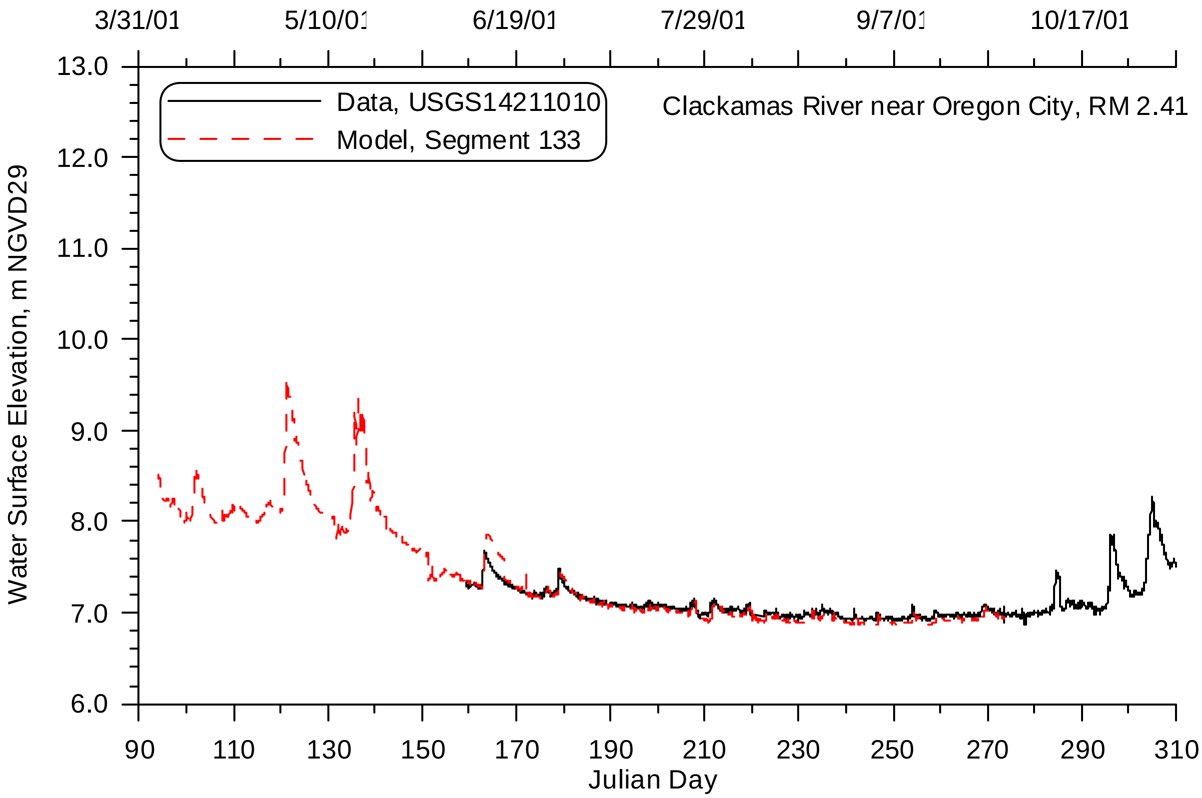

Figure 268: Clackamas River near Oregon City model-data water level comparison, 2001

Year 2002

Clackamas River hydrodynamic error statistics for the 2002 model are listed in Table 35. Plots of predicted water level and flow compared with data are shown in Figure 269 through Figure 272. The figures show there is good agreement between the model and data for flow rates indicating the model is simulating the appropriate amount of water over time. There is less agreement between the model and data regarding water level elevation at the two gage station. The differences though fall within one vertical model layer which represents conditions at high and low flows.

Table 35: Clackamas River hydrodynamic calibration model-data error statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14210000	22.22	2	8687	0.03	0.36	1.12
USGS 14211010	2.41	133	8687	7.09	8.81	18.27
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14210000	22.22	2	8687	0.37	0.37	0.47
USGS 14211010	2.41	133	8687	0.26	0.27	0.38

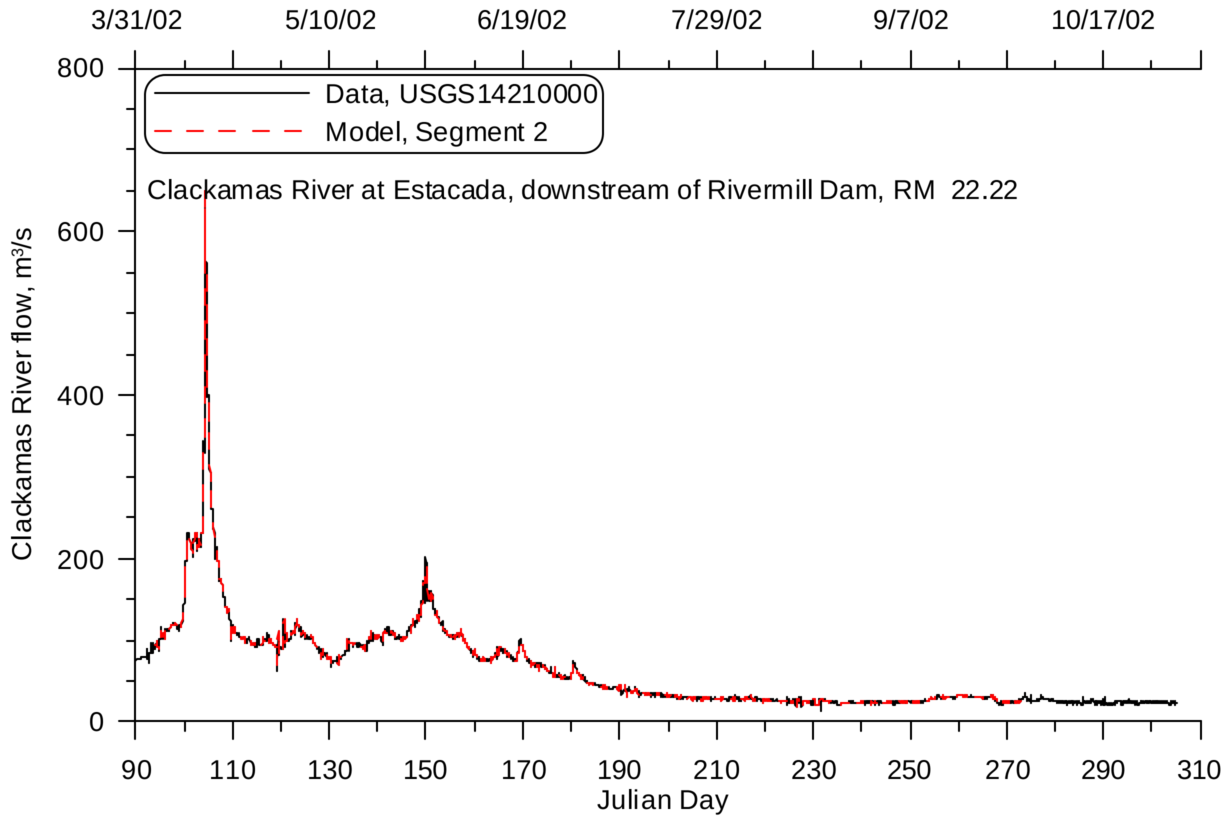

Figure 269: Clackamas River at Estacada model-data flow comparison, 2002

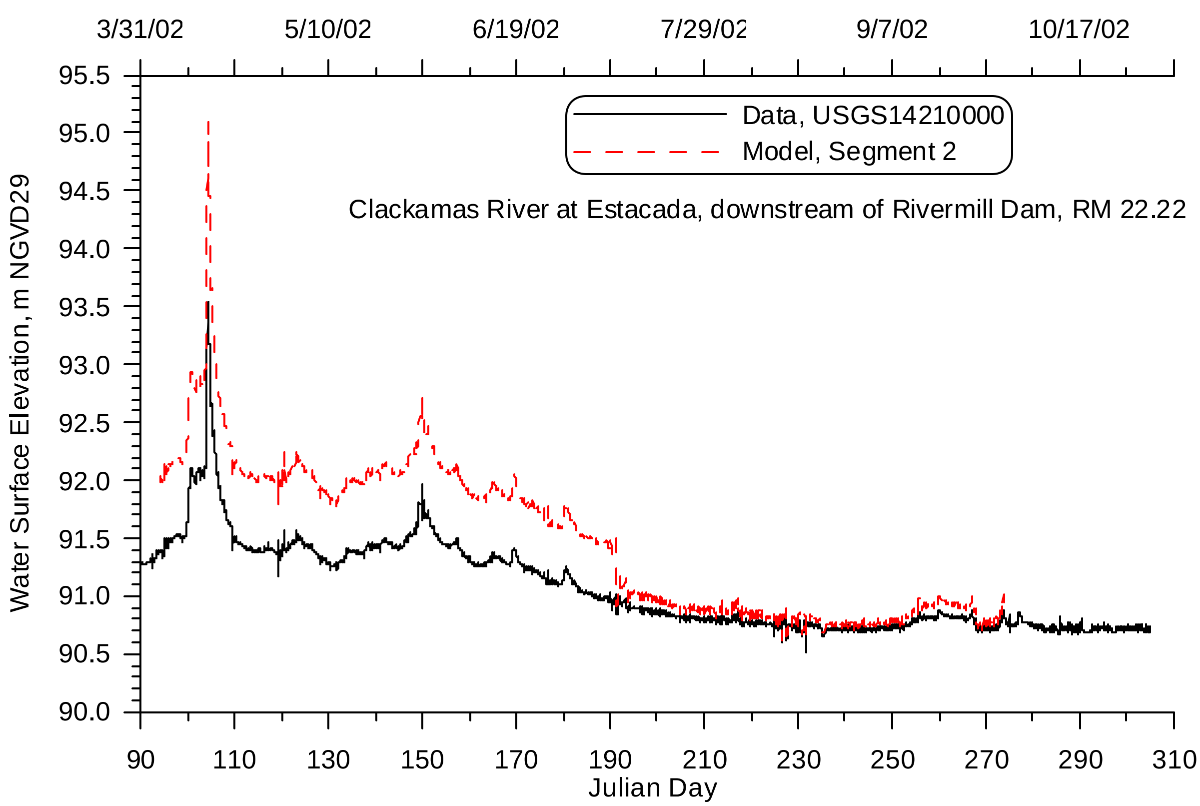

Figure 270: Clackamas River at Estacada model-data water level comparison, 2002

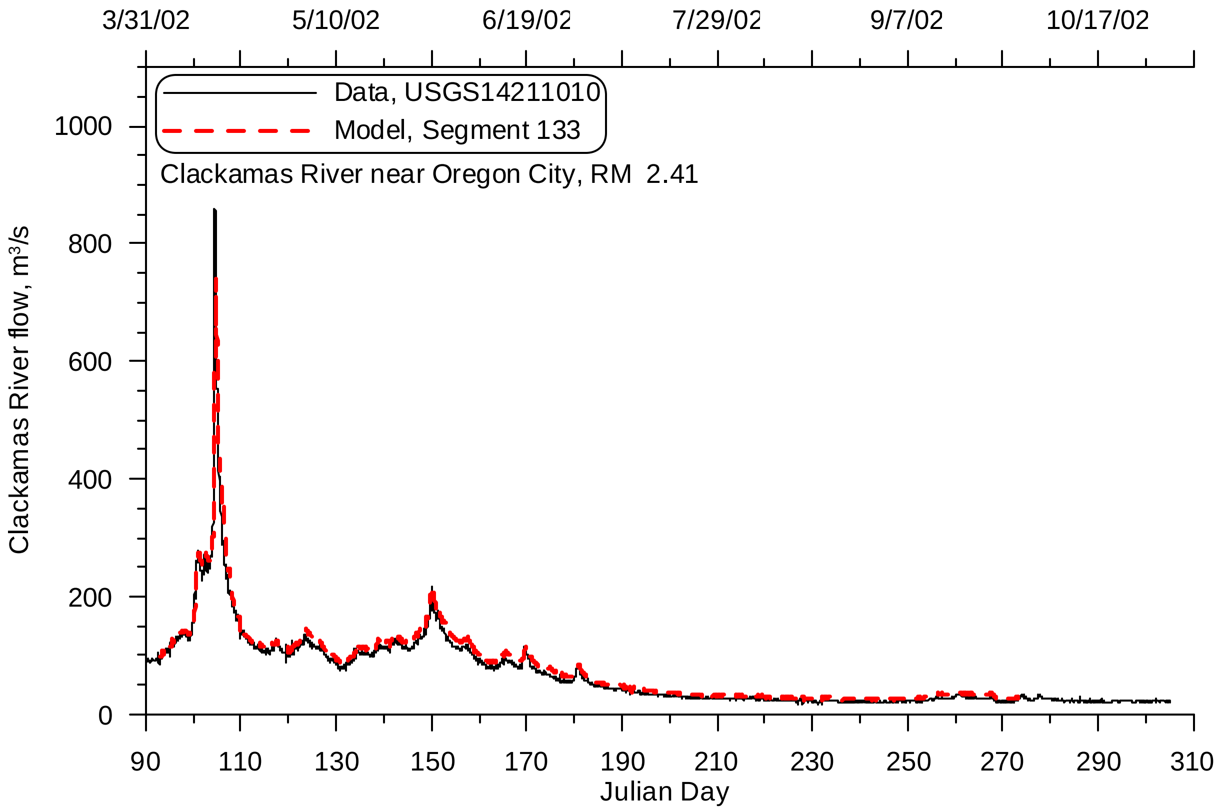

Figure 271: Clackamas River near Oregon City model-data flow comparison, 2002

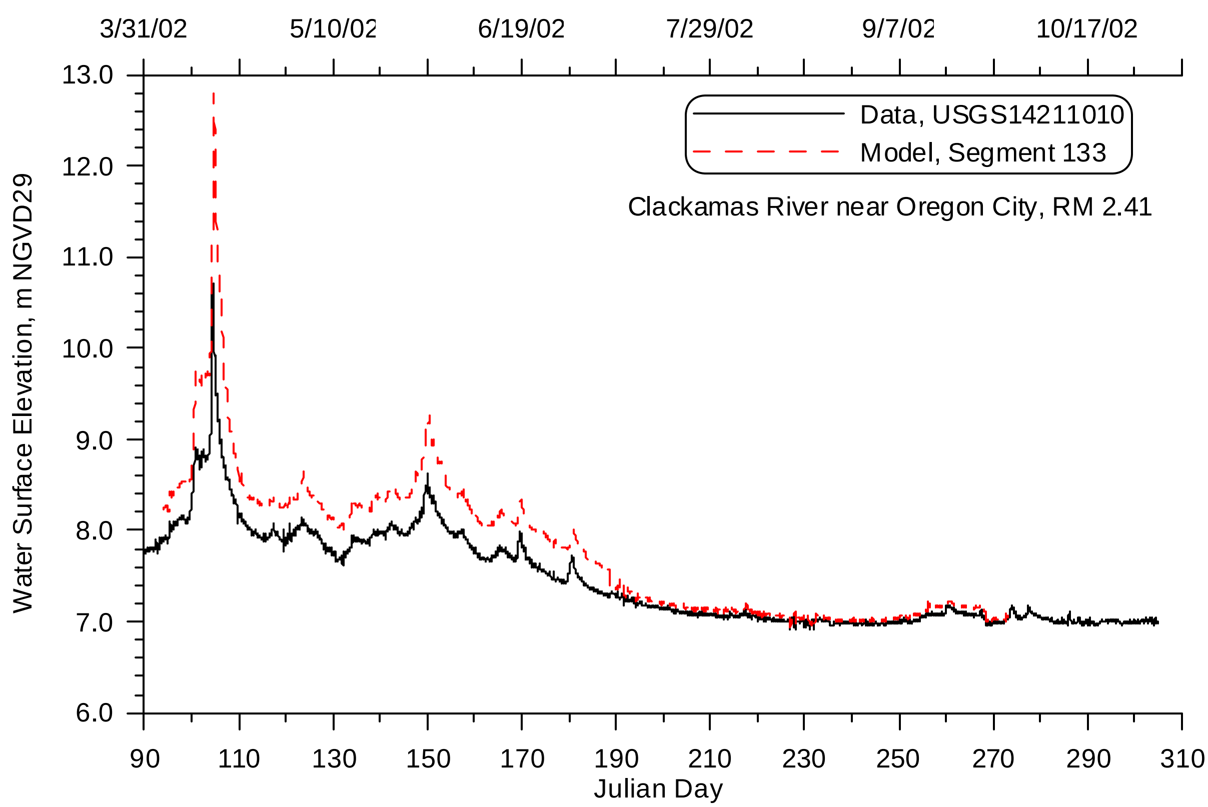

Figure 272: Clackamas River near Oregon City model-data water level comparison, 2002

Channel Widths

There were two types of data utilized for comparing with simulated stream widths. The first data set is comprised of channel widths collected by the U.S. Geological Survey as part of two field surveys conducted in the spring and summer of 2002. The second data set consists of wetted channel widths identified from digital ortho-rectified aerial photographs associated with each 7.5 minute quadrangle map in a GIS database developed by the Oregon Department of Environmental Quality.

USGS Width Survey

In 2002 the U.S. Geological Survey conducted two field surveys of channel widths on the Clackamas River. The surveys were conducted on April 8, with higher stream flows and August 5, when the flows would be at their summer lows. Figure 273 shows the location of the survey sites. Table 36 lists the survey sites, the river mile location, and corresponding survey dates. The model was run in 2002 for calibration so channel widths were output from the model corresponding to the survey data's date, time, and location. Figure 274 and Figure 275 show the comparison with measured widths and model widths on 4/8/02 and 8/5/02, respectively. The two figures indicate there is relatively good agreement between the model and data with more agreement in during April than August. The channel widths predicted by the model had to be balanced with the hydrodynamic and temperature calibration as well.

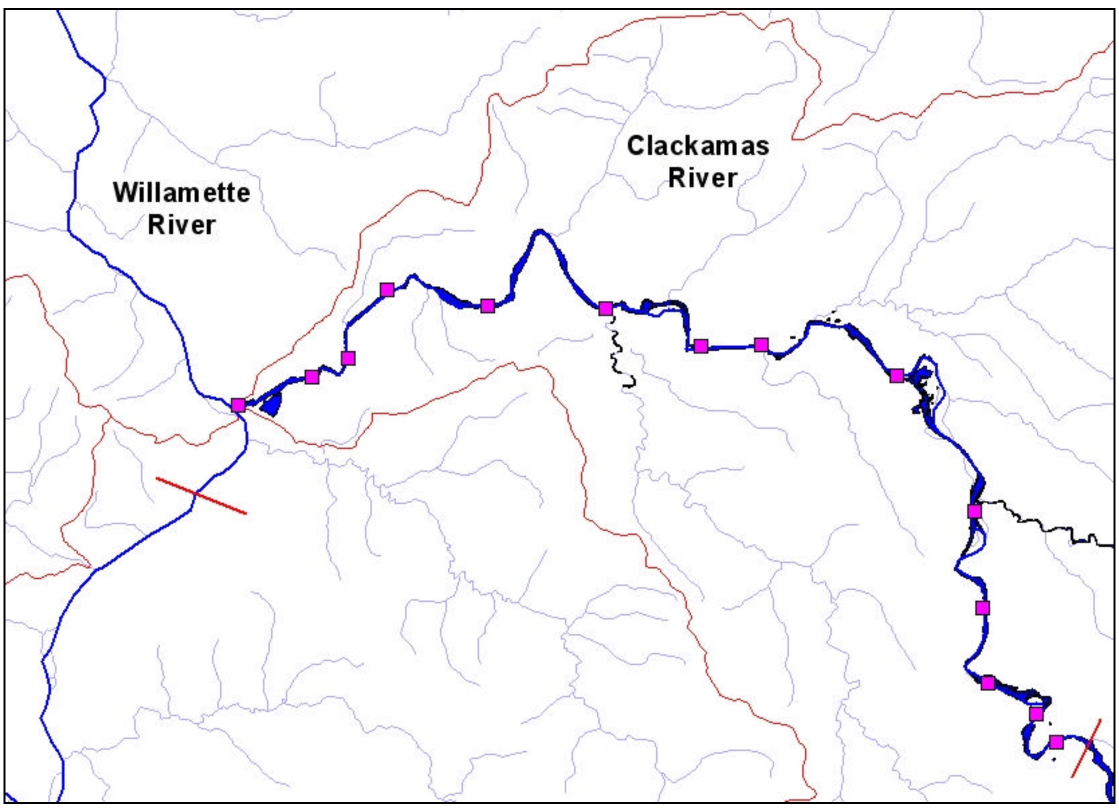

Figure 273: Clackamas River USGS width survey site locations

Table 36: Clackamas River USGS width survey sites and dates

Site Name	River Mile	Model Segment	Date 1	Date 2

Site Name	River Mile	Model Segment	Date 1	Date 2
McIver State Park, boat launch	22.78	5	04/08/2002	08/05/2002
McIver State Park, picnic area	21.08	12	04/08/2002	08/05/2002
McIver State Park, unimproved boat ramp	19.87	19	04/08/2002	08/05/2002
Feldheimer Ferry	18.45	29	04/08/2002	08/05/2002
Bonnie Lure State Park	16.59	40	04/08/2002	08/05/2002
Barton Canby Park	13.92	57	04/08/2002	08/05/2002
Downstream of Deep Creek	11.21	75	04/08/2002	08/05/2002
Near Semple Road	10.32	80	04/08/2002	08/05/2002
Carver Bridge	8.28	97	04/08/2002	08/05/2002
Near river mile 5	5.06	116	04/08/2002	08/05/2002
Clackamas River Water Park	3.28	128	04/08/2002	08/05/2002
Upstream of I-205	1.99	136	04/08/2002	08/05/2002
Downstream of I-205	1.23	141	04/08/2002	08/05/2002
River Mouth	0.00	148	04/08/2002	08/05/2002

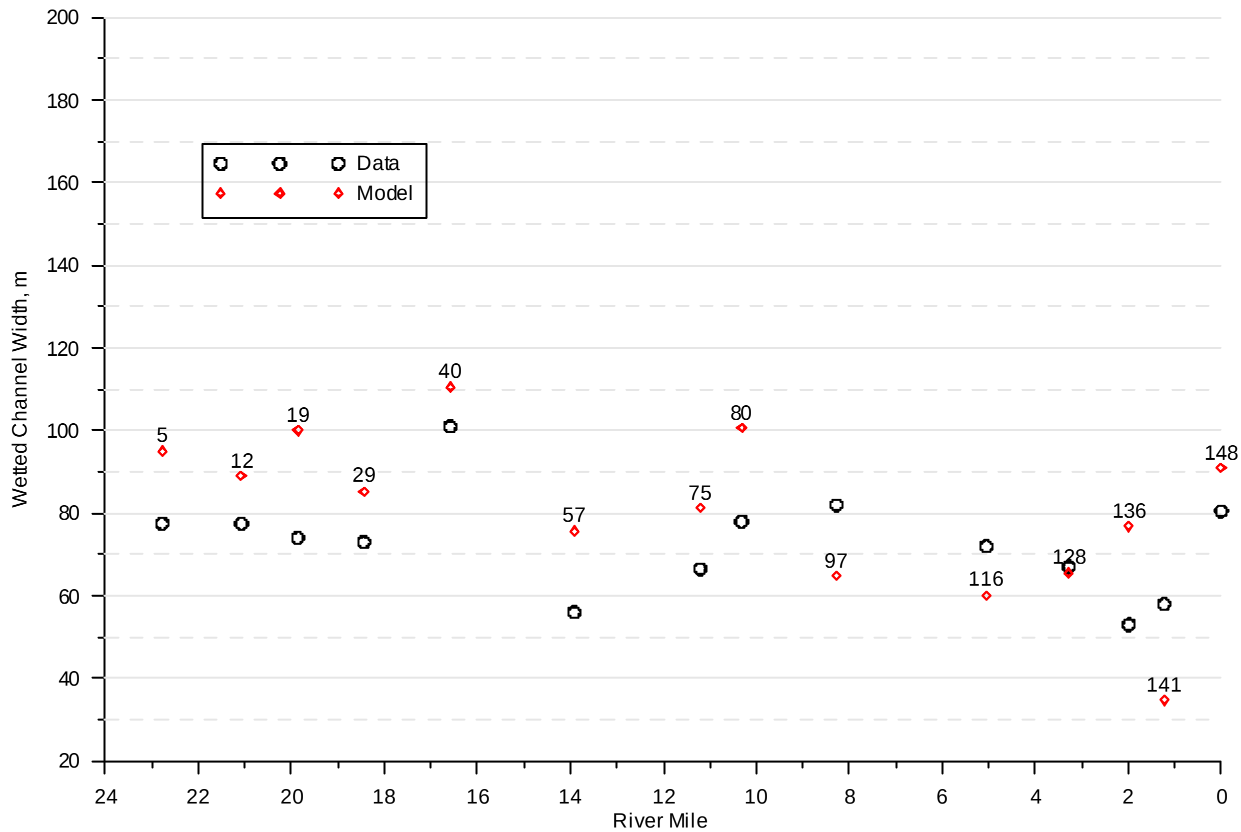

Figure 274: Clackamas River model simulated widths compared with data measured on 4/8/02.

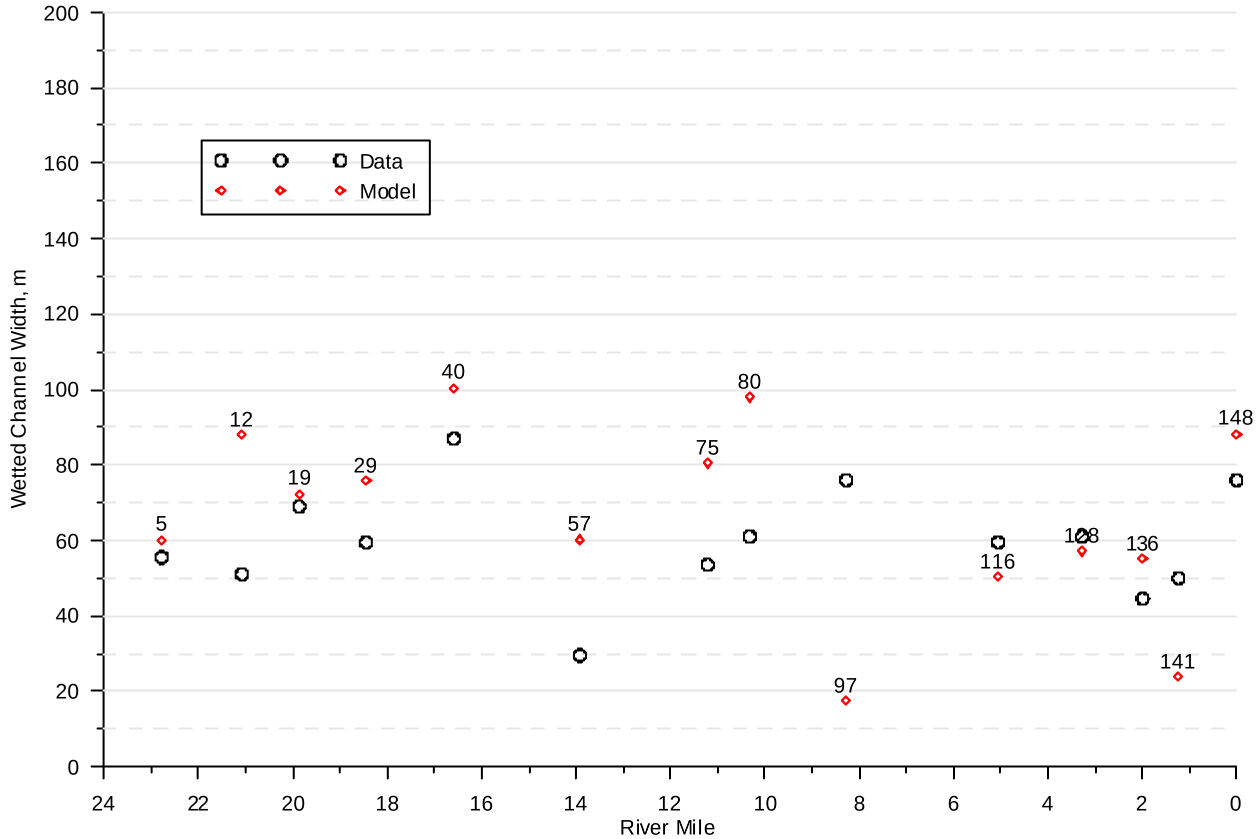

Figure 275: Clackamas River model simulated compared with data measured on 8/5/02.

Water Temperature

Water temperature was calibrated using continuous temperature data recorded every half hour or hour at several locations in the basin. Additionally model-data comparisons were made both at small time scales and at large time scales over the simulation period to ensure diurnal fluctuations were simulated accurately. Calibration parameters included adjusting the Manning's friction factor, channel widths, wind sheltering, evaporation, and sediment temperatures. Vegetative and topographic shade characteristics were not adjusted since the model input was developed using a detailed GIS analysis.

The Clackamas River has nine sites where continuous temperatures were recorded for calibrating the model. Temperatures were recorded by Portland General Electric (PGE), Oregon Department of Environmental Quality (ODEQ), and the U.S. Geological Survey (USGS). Figure 276 shows a map of the basin with the gage site locations and Table 37 shows a list of the gage sites with RM and corresponding model segment.

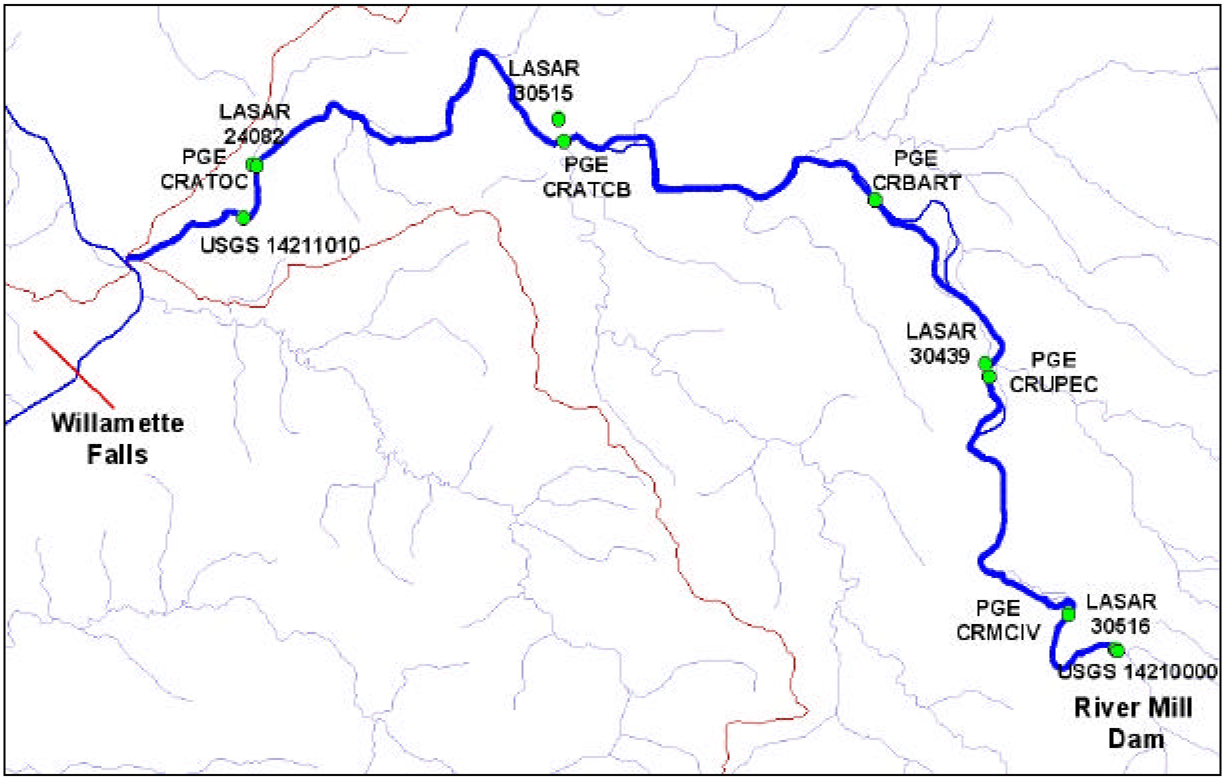

Figure 276: Clackamas River water temperature calibration site locations

Table 37: Clackamas River water temperature calibration sites

Site ID	Site Description	RM	Model Segment
USGS 14210000	Clackamas River at Estacada, downstream of Rivermill Dam	22.22	2
LASAR 30516	Clackamas River at Rivermill Tailrace	22.22	2
PGE CRMCIV	Clackamas River at lower boat ramp at McIver Park	20.64	12
PGE CRUPEC, LASAR 30439	Clackamas River immediately upstream of Eagle Creek	16.30	41
PGE CRBART	Clackamas River at Barton	13.25	60
LASAR 30515	Clackamas River upstream of Clear Creek	8.20	92
PGE CRATCB	Clackamas River at Carver Bridge	8.11	93
PGE CRATOC, LASAR 24082	Clackamas River at Oregon City	2.41	133
USGS 14211010	Clackamas River near Oregon City	2.41	133

The model was calibrated by comparing the continuous temperature data and model results but since the model will be used for running model scenarios examining the daily maximum temperature model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

Model-data error statistics of continuous water temperature for the 2001 Clackamas River model are listed in Table 38. Figure 277 through Figure 282 compares model prediction with data for year 2001 predicted temperatures. The time series comparison plots indicate the model is doing well in simulating the diurnal variations with a few site with slightly cooler nights than the data. Model-data error statistics are below 0.90 ^{o}C. Light extinction was set to a value of 0.45 m^{-1}. Wind sheltering values were varied, with higher values used upstream and lower values were applied downstream.

Table 38: Clackamas River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14210000	22.22	2	3831	0.01	0.02	0.03
PGE CRMCIV	20.64	12	3934	0.02	0.52	0.72
PGE CRUPEC	16.30	41	4379	0.15	0.66	0.85
PGE CRBART	13.25	60	3852	-0.13	0.60	0.73
PGE CRATCB	8.11	93	4306	-0.01	0.67	0.84
PGE CRATOC	2.41	133	4379	-0.14	0.69	0.86

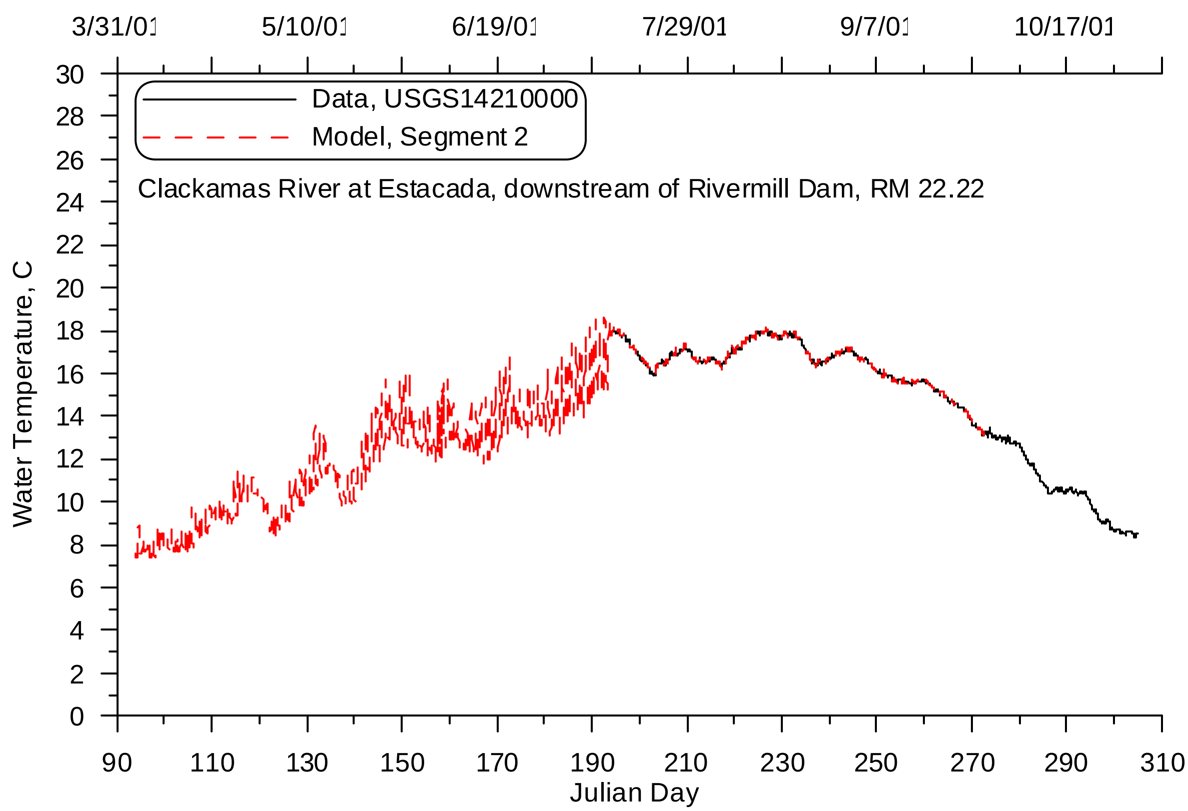

Figure 277: Clackamas River at Estacada model-data continuous temperature comparison, 2001

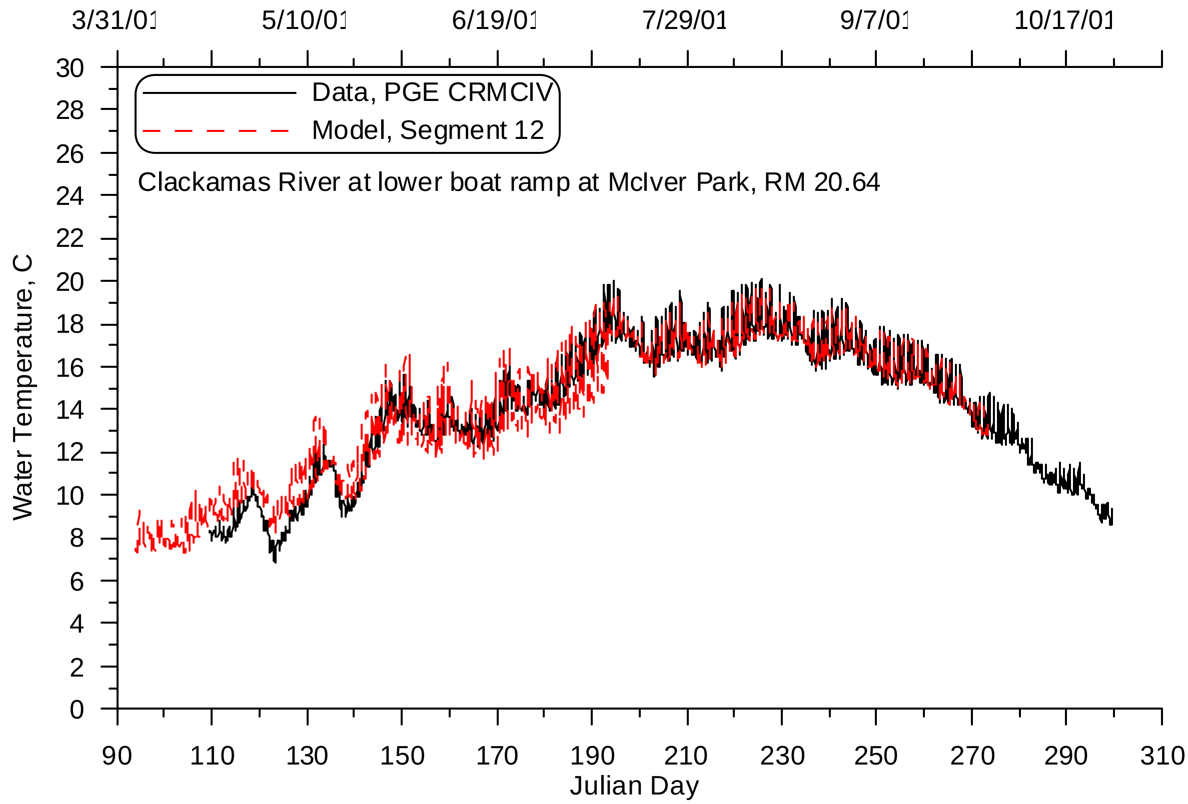

Figure 278: Clackamas River at McIver Park model-data continuous temperature comparison, 2001

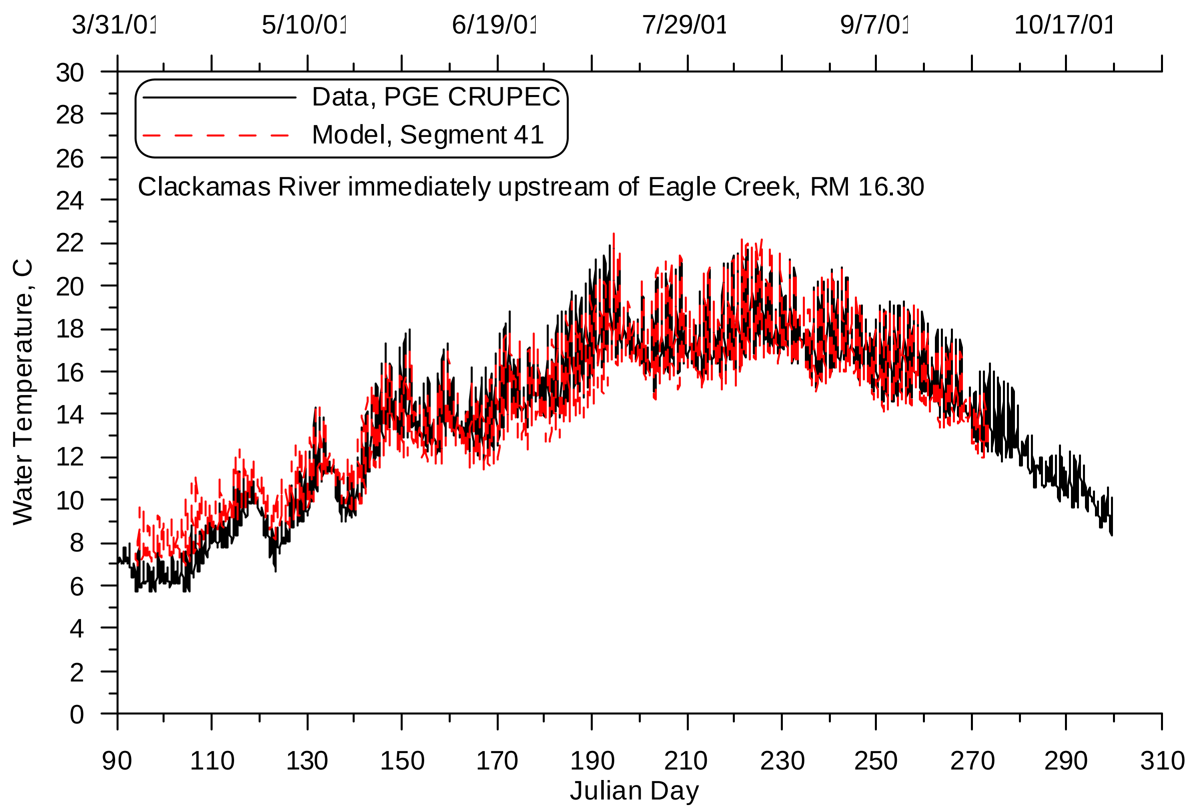

Figure 279: Clackamas River upstream of Eagle Creek model-data continuous temperature comparison, 2001

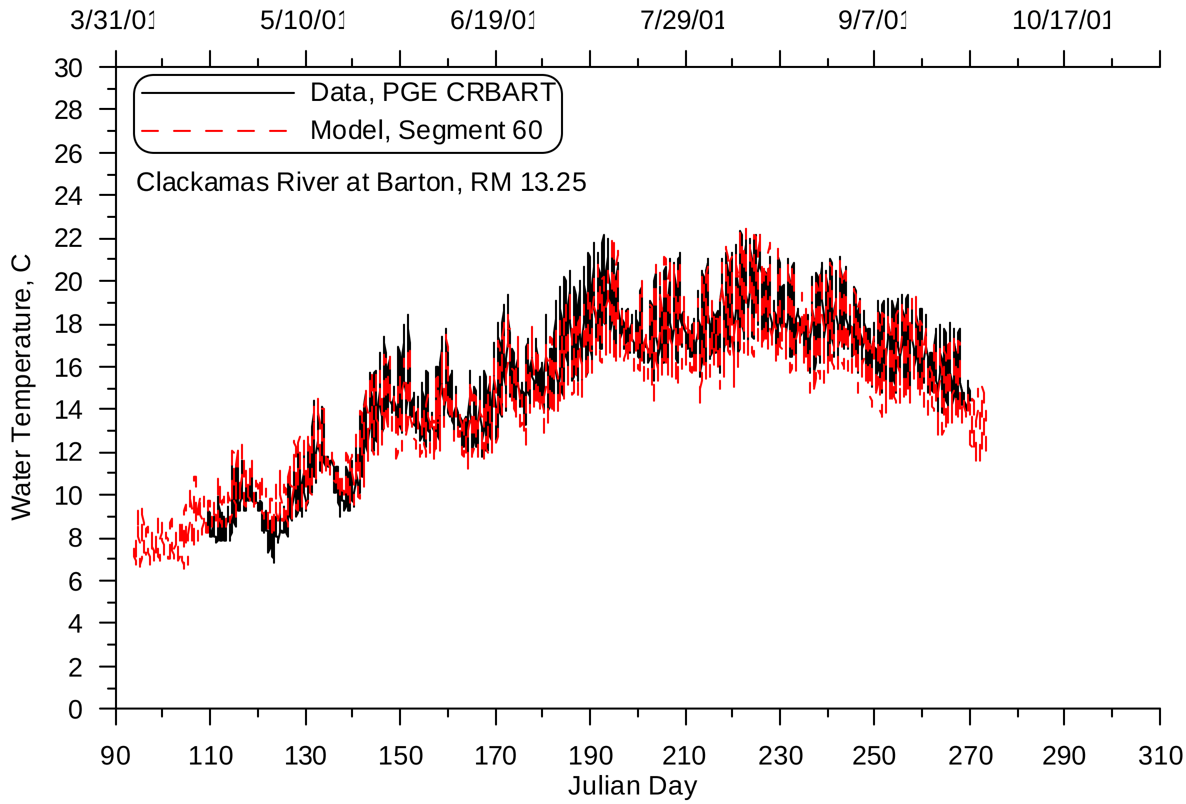

Figure 280: Clackamas River at Barton model-data continuous temperature comparison, 2002

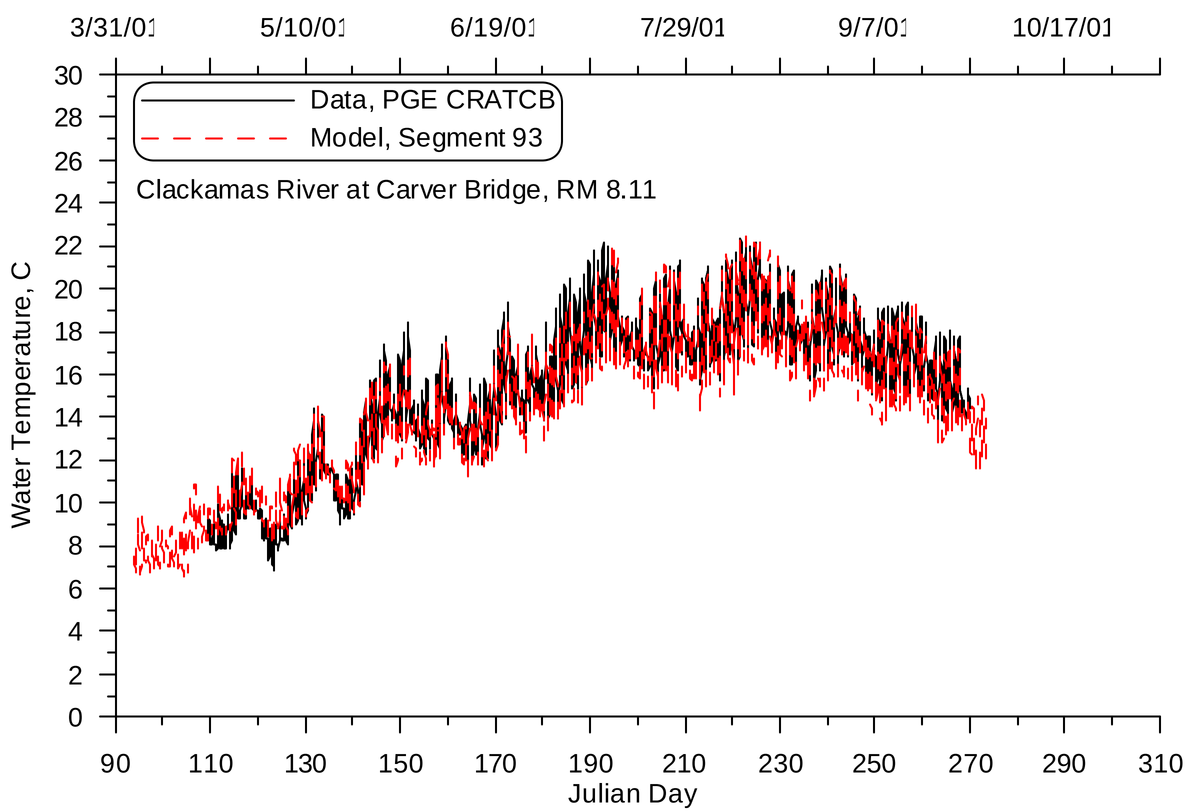

Figure 281: Clackamas River at Carver Bridge model-data continuous temperature comparison, 2001

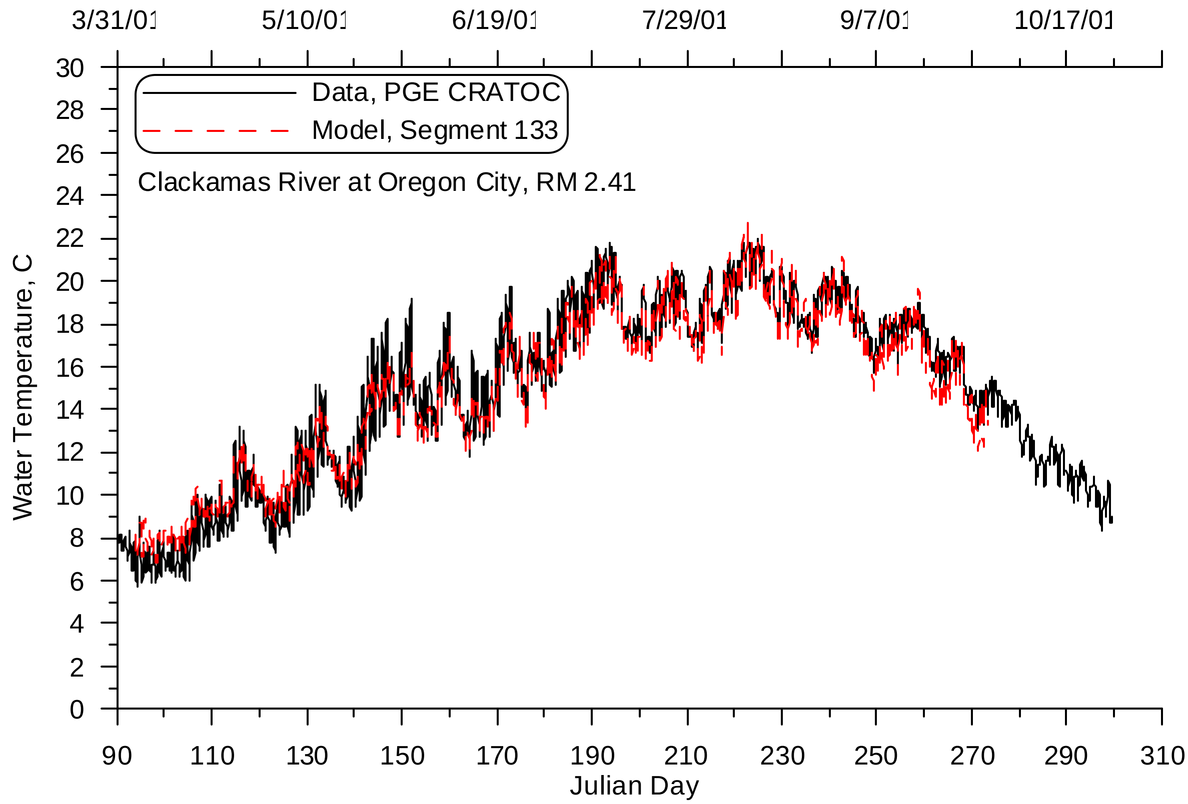

Figure 282: Clackamas River at Oregon City model-data continuous temperature comparison, 2001

Year 2002

Model-data error statistics of continuous water temperature are listed in Table 39. Time series plots comparing model and data continuous temperatures are shown in Figure 283 through Figure 288. Similar to 2001 the continuous temperature results in the time series comparisons show the model is doing well simulating the diurnal temperature swings. Model-data error statistics are below 0.70 ^{o}C.

Table 39: Clackamas River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14210000	22.22	2	8783	0.01	0.02	0.03
LASAR 30516	22.22	2	1310	0.11	0.13	0.15
LASAR 30439	16.30	41	1309	-0.26	0.35	0.45
LASAR 30515	8.20	92	1307	-0.32	0.53	0.63
USGS 14211010	2.41	133	4922	-0.39	0.52	0.63
LASAR 24082	2.41	133	2625	-0.42	0.57	0.68

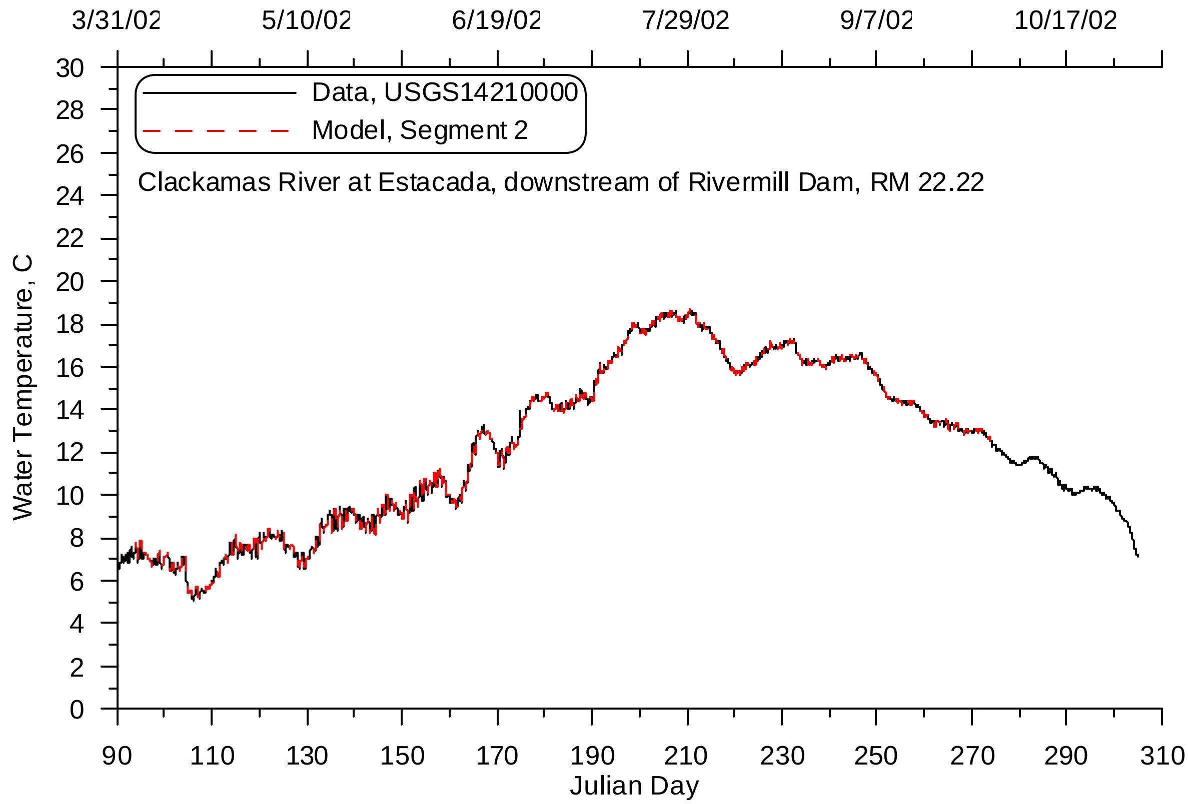

Figure 283: Clackamas River at Estacada model-data continuous temperature comparison, 2002

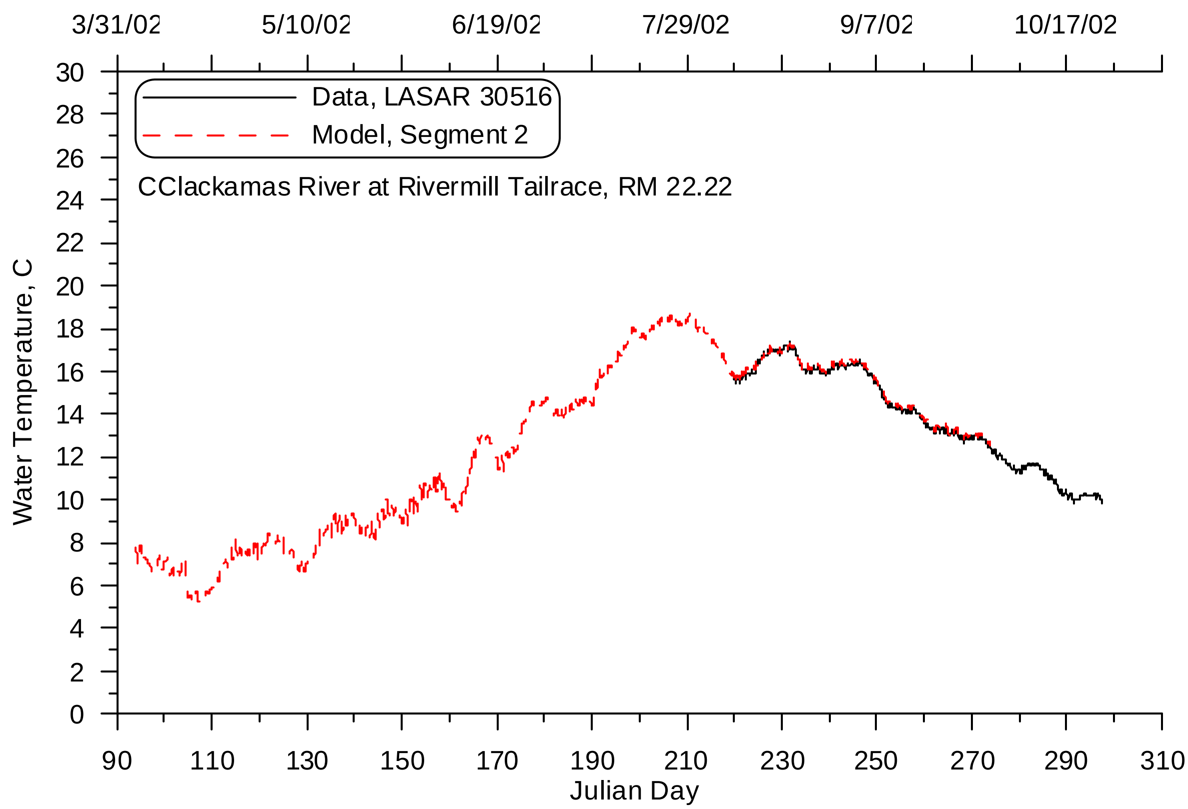

Figure 284: Clackamas River at Rivermill Tailrace model-data continuous temperature comparison, 2002

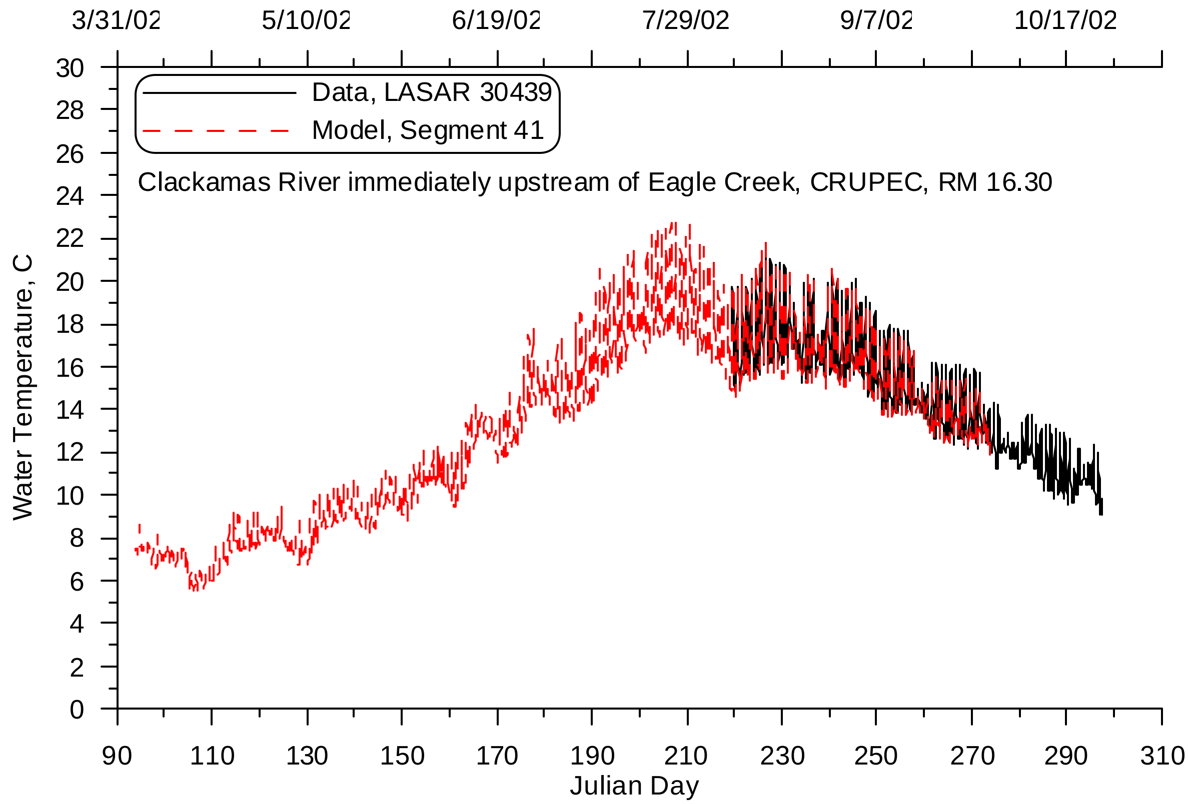

Figure 285: Clackamas River upstream of Eagle Creek model-data continuous temperature comparison, 2002

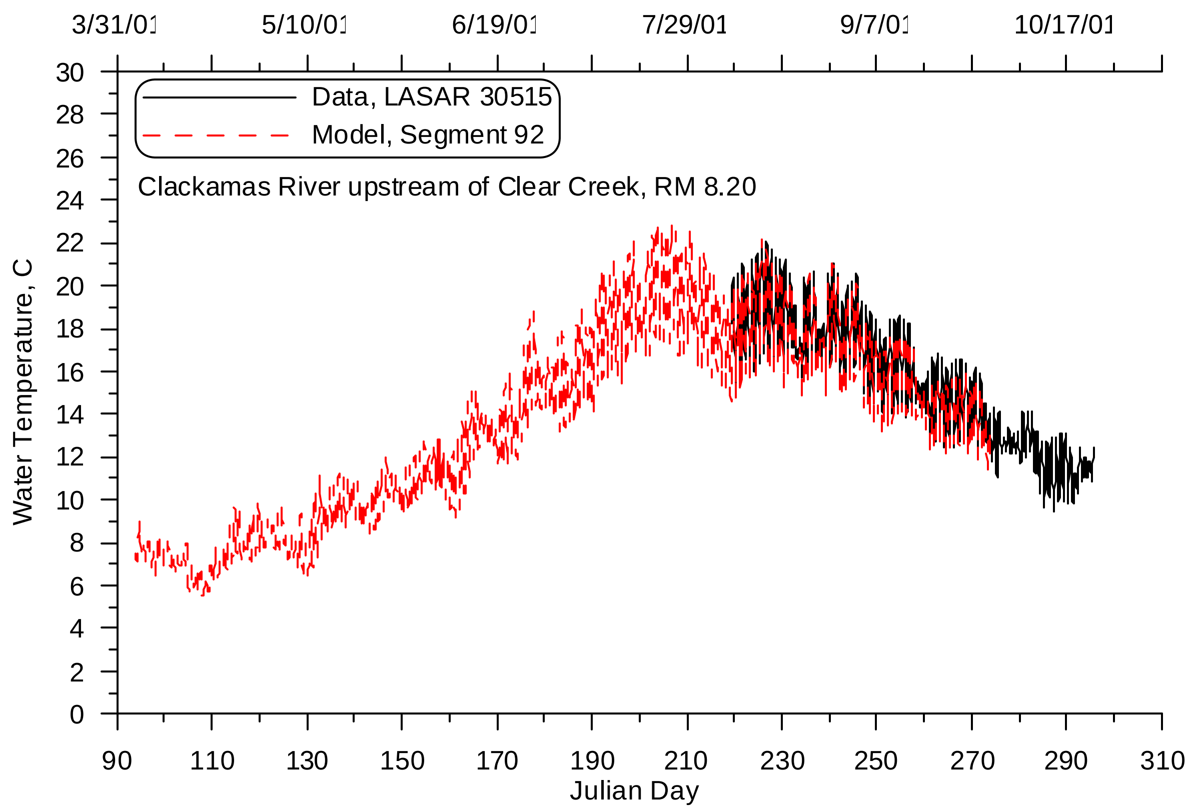

Figure 286: Clackamas River upstream of Clear Creek model-data continuous temperature comparison, 2002

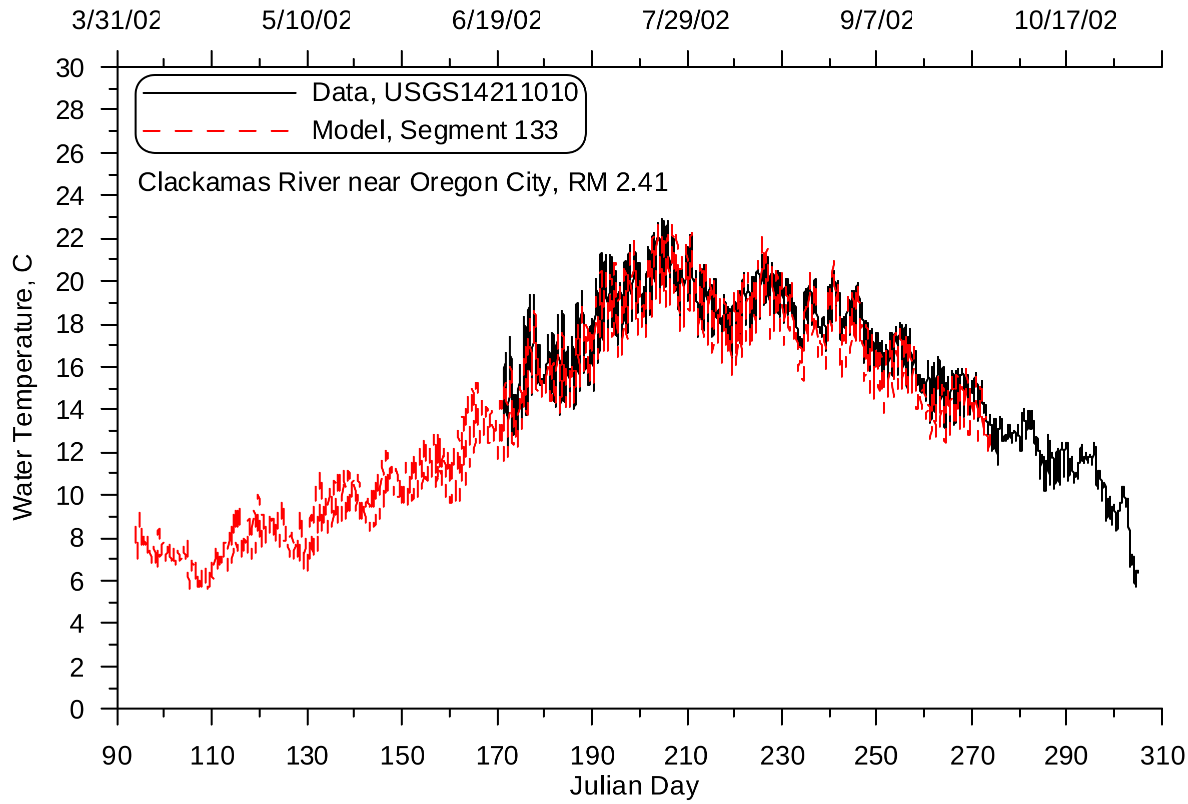

Figure 287: Clackamas River at Oregon City model-data continuous temperature comparison, 2002

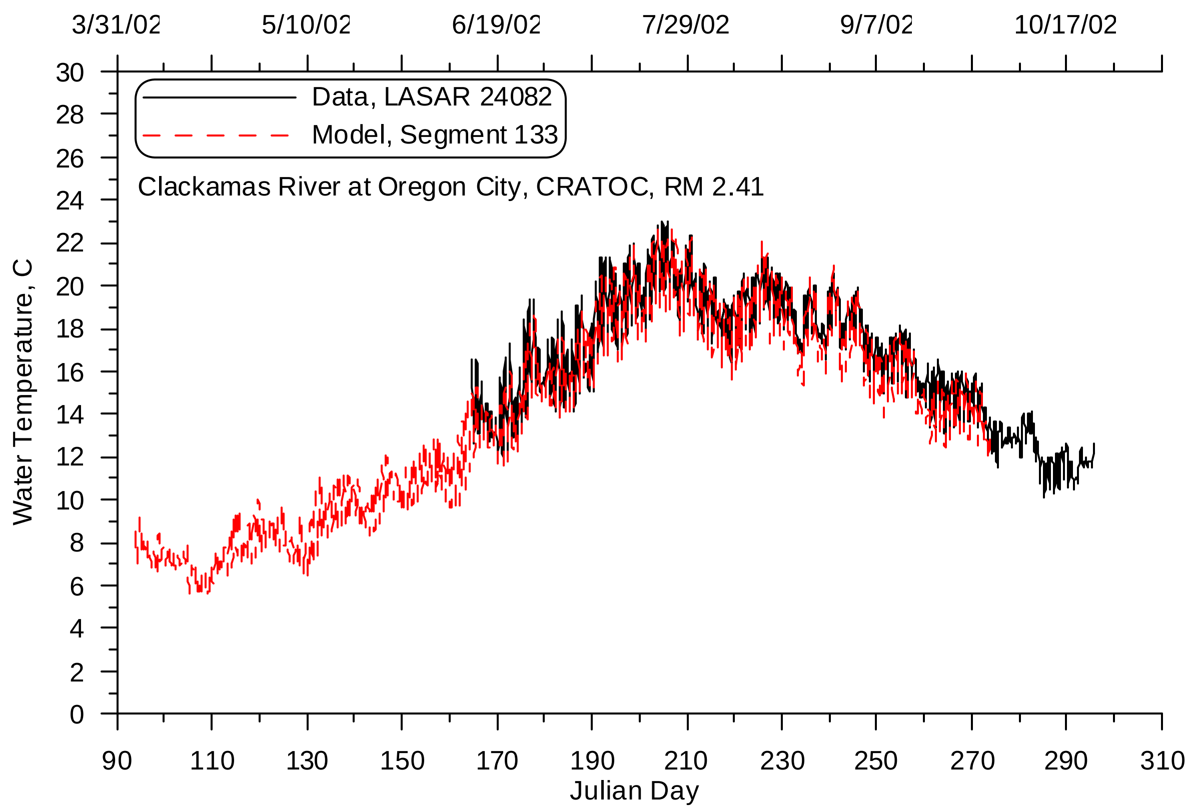

Figure 288: Clackamas River at Oregon City model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

Year 2001

Model-data error statistics of daily maximum temperature for the Clackamas River 2001 model are listed in Table 40. Figure 289 through Figure 294 show comparisons between model predicted daily maximum temperature and data for the Lower Clackamas River. Although the continuous temperature model results show a few sites with slightly cooler night time temperatures the model does well at the Lower Clackamas River sites simulating the daily maximum temperature over the period from April to October, 2001.

Table 40: Clackamas River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14210000	22.22	2	81	0.03	0.04	0.08
PGE CRMCIV	20.64	12	165	0.33	0.63	0.84
PGE CRUPEC	16.30	41	182	0.24	0.73	0.92
PGE CRBART	13.25	60	160	-0.13	0.57	0.72
PGE CRATCB	8.11	93	180	-0.41	0.72	0.94
PGE CRATOC	2.41	133	182	-0.33	0.66	0.87

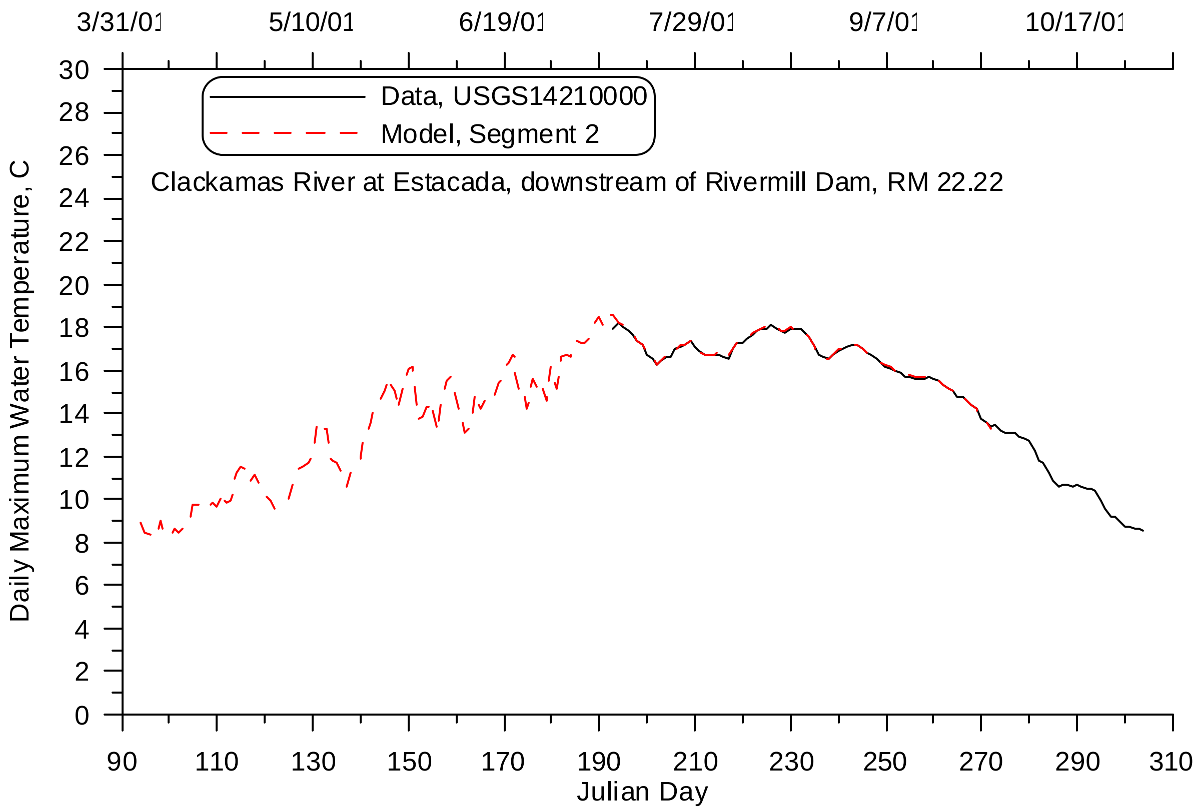

Figure 289: Clackamas River at Estacada model-data daily maximum temperature comparison, 2001

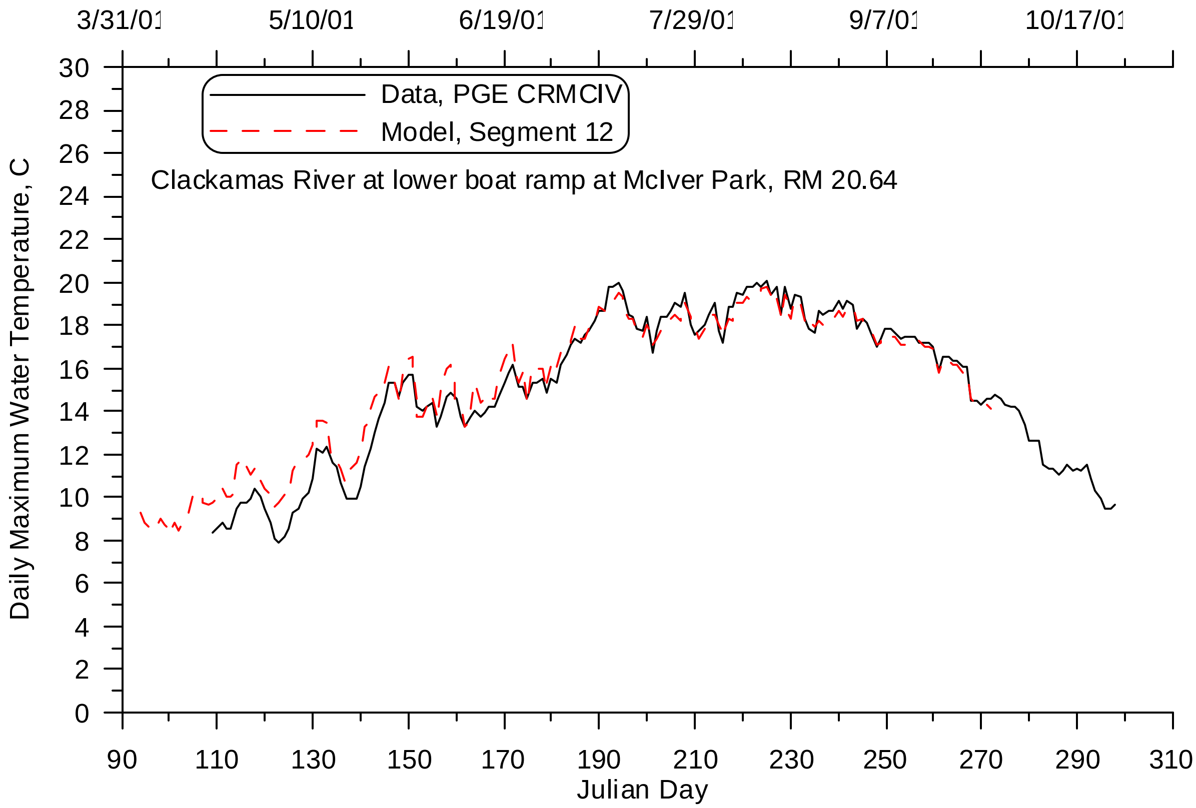

Figure 290: Clackamas River at McIver Park model-data daily maximum temperature comparison, 2001

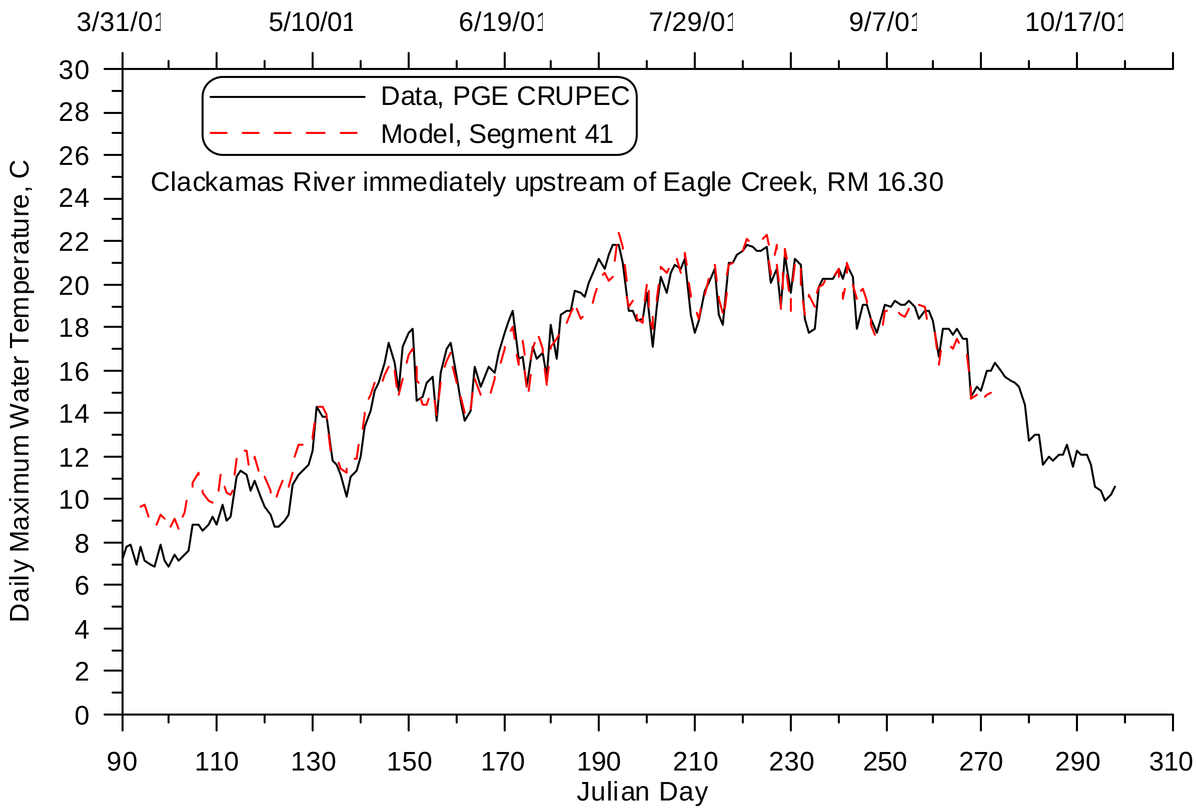

Figure 291: Clackamas River upstream of Eagle Creek model-data daily maximum temperature comparison, 2001

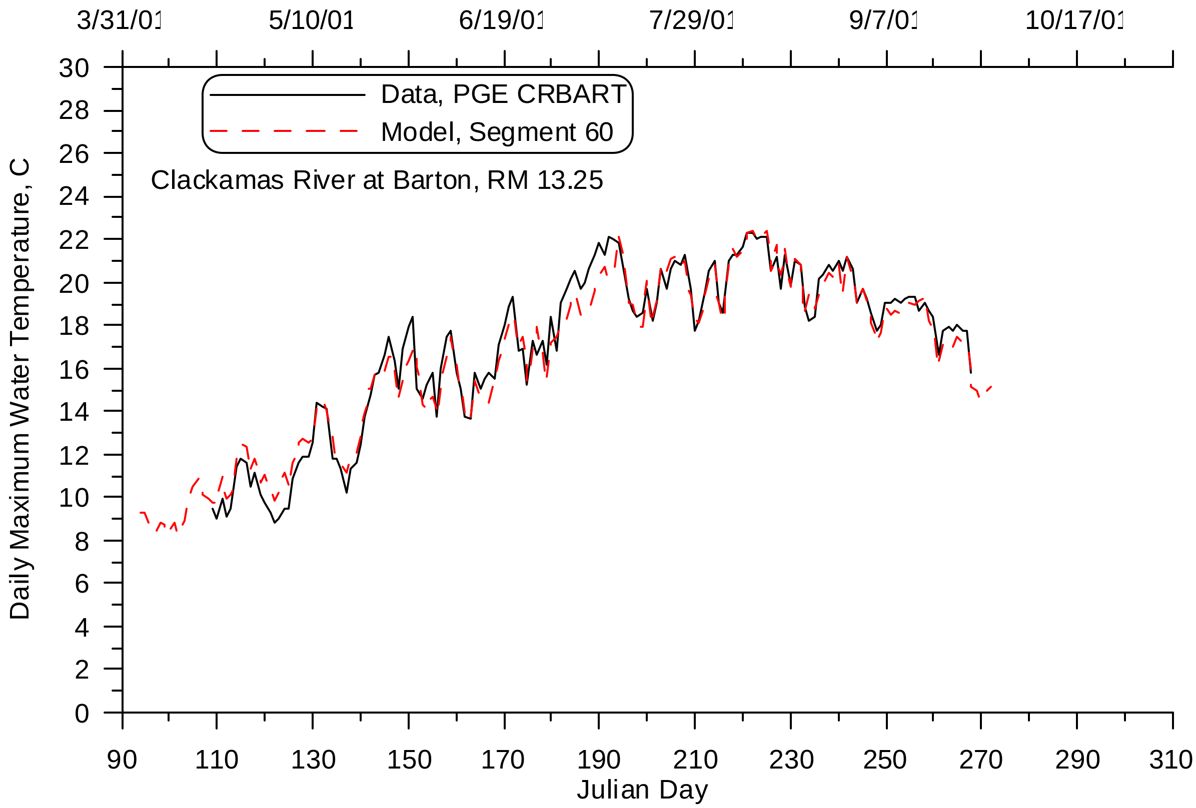

Figure 292: Clackamas River at Barton model-data daily maximum temperature comparison, 2002

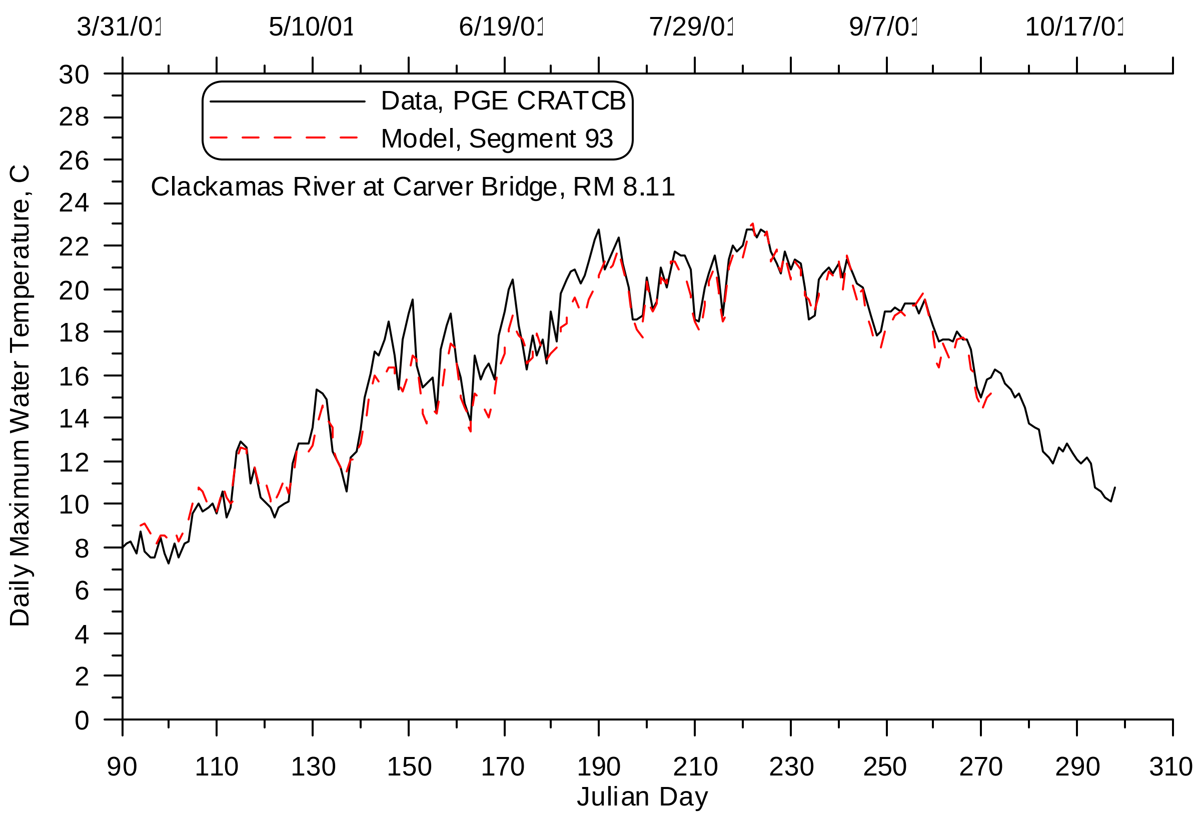

Figure 293: Clackamas River at Carver Bridge model-data daily maximum temperature comparison, 2001

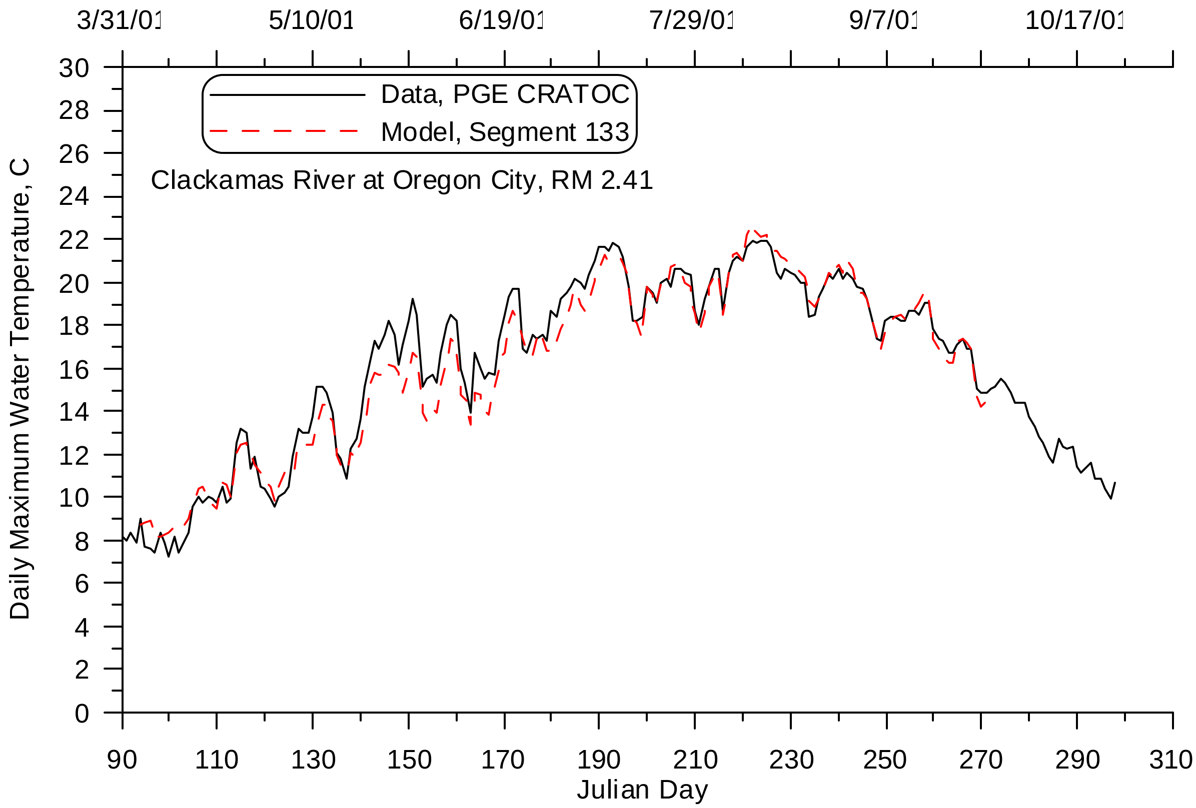

Figure 294: Clackamas River at Oregon City model-data daily maximum temperature comparison, 2001

Year 2002

Table 41 lists model-data error statistics for daily maximum water temperature for the 2002 Clackamas River model. Figure 295 through Figure 300 show daily maximum water temperature predictions compared with year 2002 data. The time series comparison figures show the model is doing well compared to data in simulating the daily maximum temperatures.

Table 41: Clackamas River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14210000	22.22	2	183	0.00	0.03	0.08
LASAR 30516	22.22	2	56	0.12	0.13	0.15
LASAR 30439	16.30	41	56	-0.28	0.38	0.48
LASAR 30515	8.20	92	56	-0.52	0.58	0.67
USGS 14211010	2.41	133	104	-0.34	0.46	0.59
LASAR 24082	2.41	133	111	-0.40	0.50	0.64

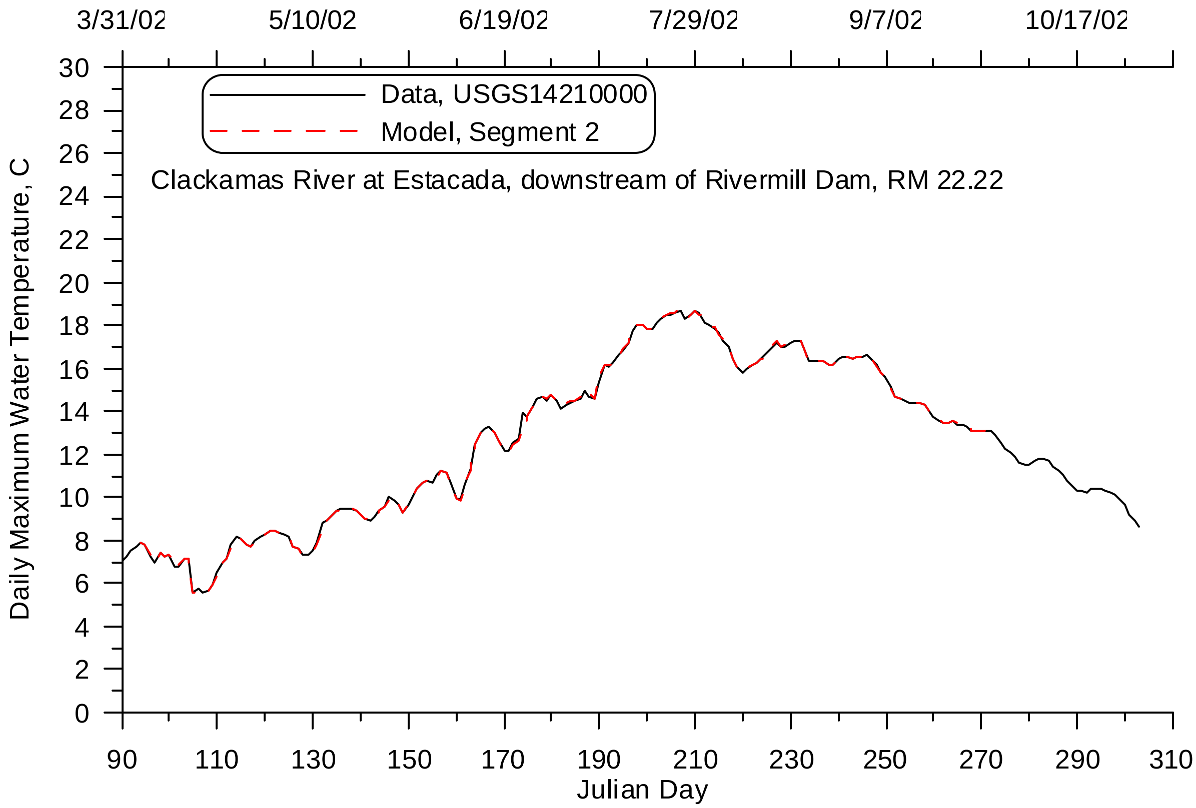

Figure 295: Clackamas River at Estacada model-data daily maximum temperature comparison, 2002

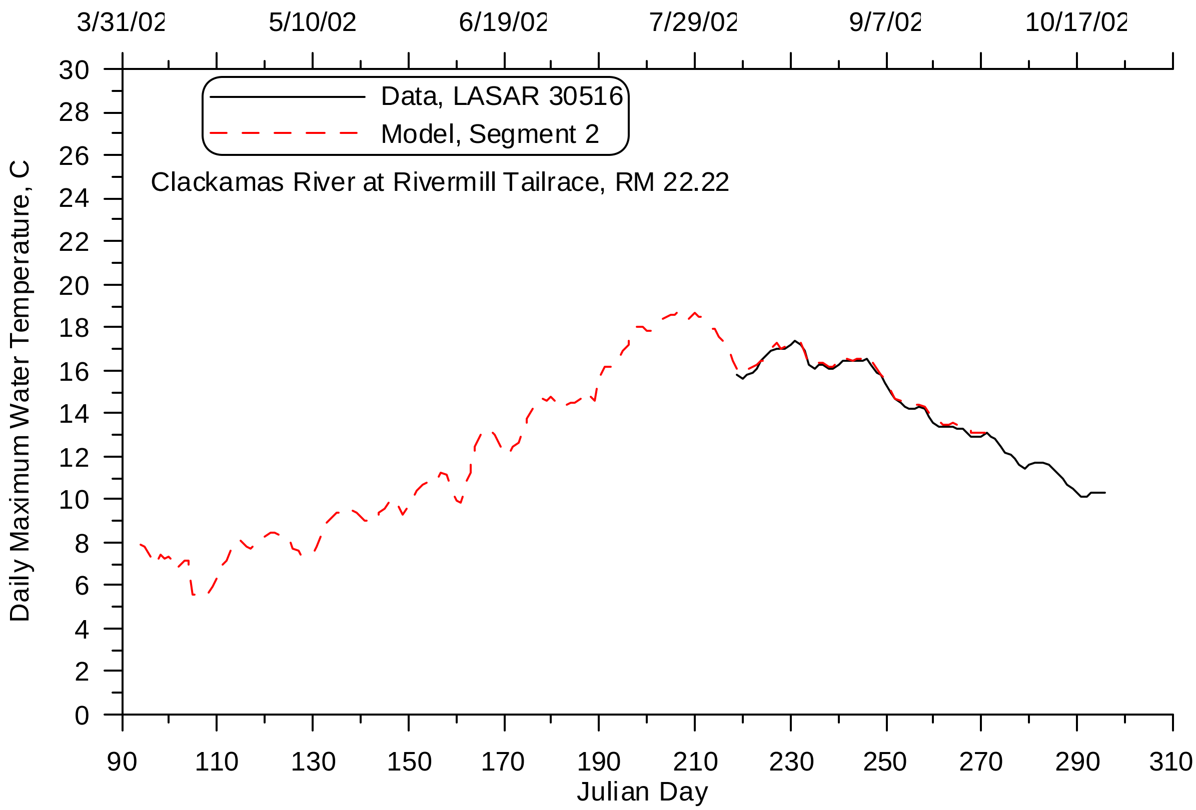

Figure 296: Clackamas River at Rivermill Tailrace model-data daily maximum temperature comparison, 2002

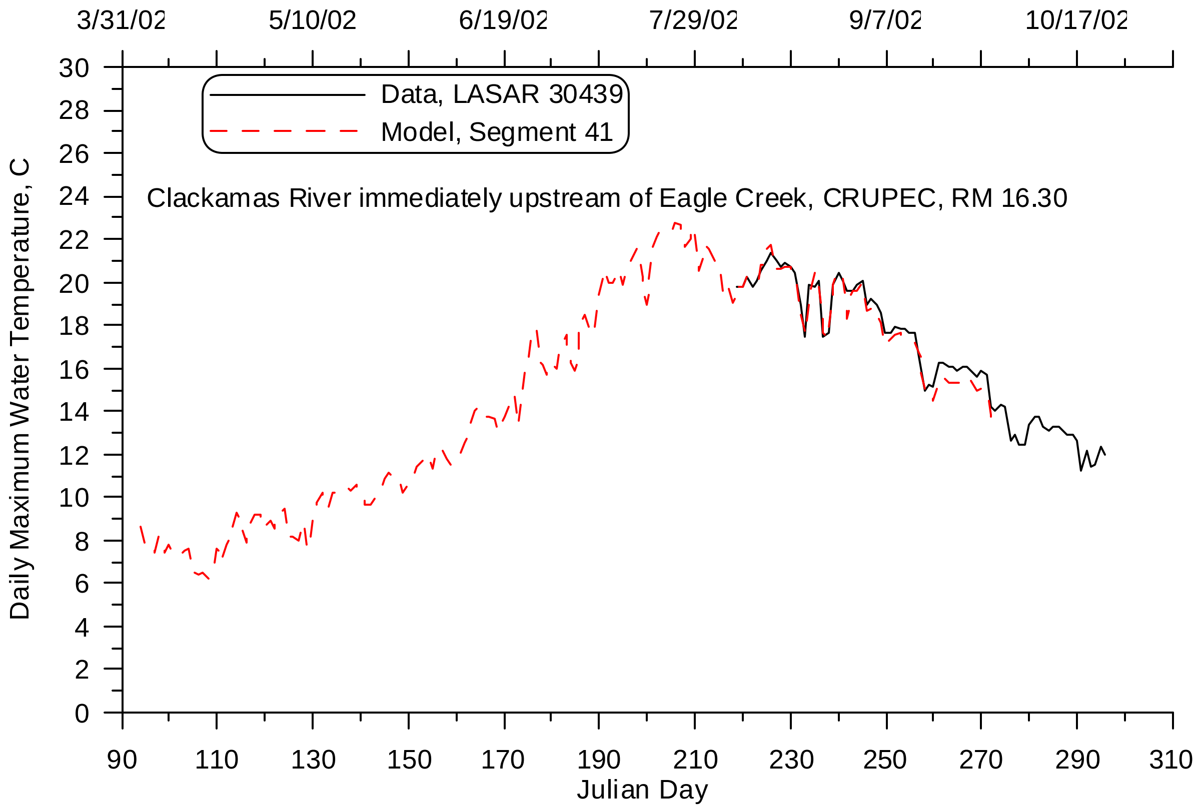

Figure 297: Clackamas River upstream of Eagle Creek model-data daily maximum temperature comparison, 2002

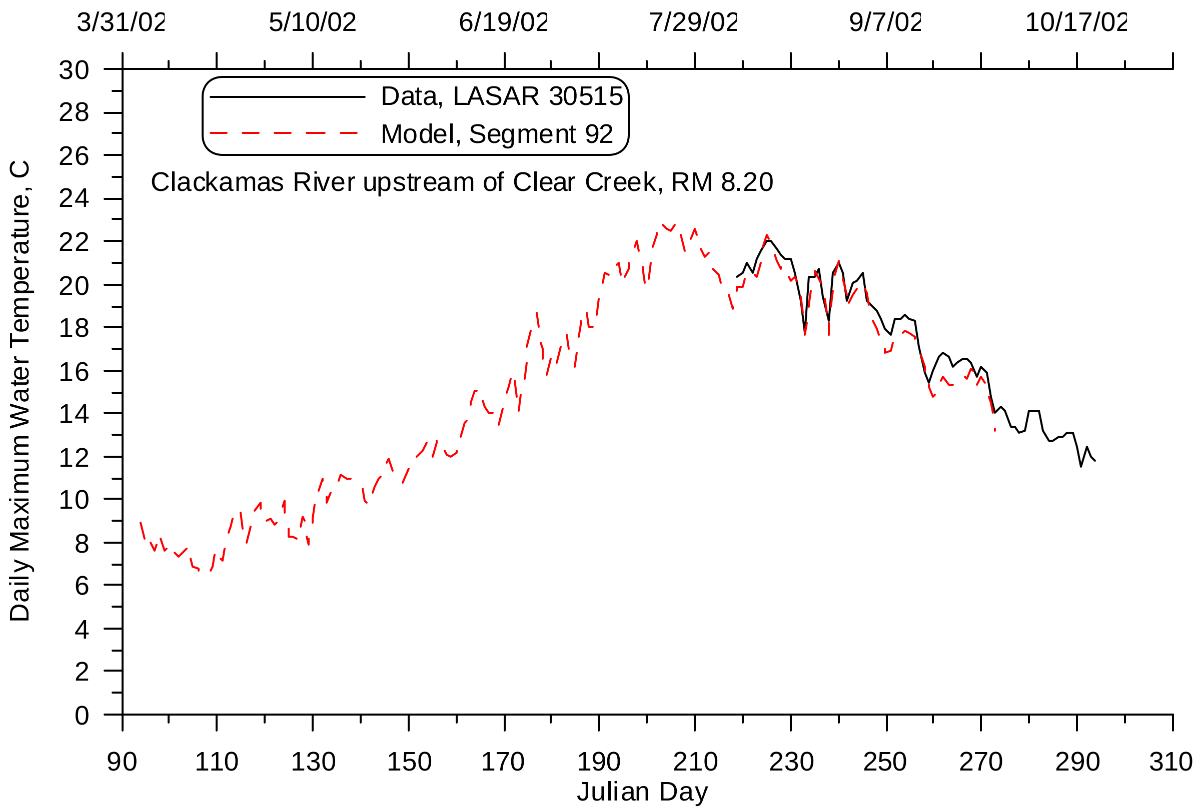

Figure 298: Clackamas River upstream of Clear Creek model-data daily maximum temperature comparison, 2002

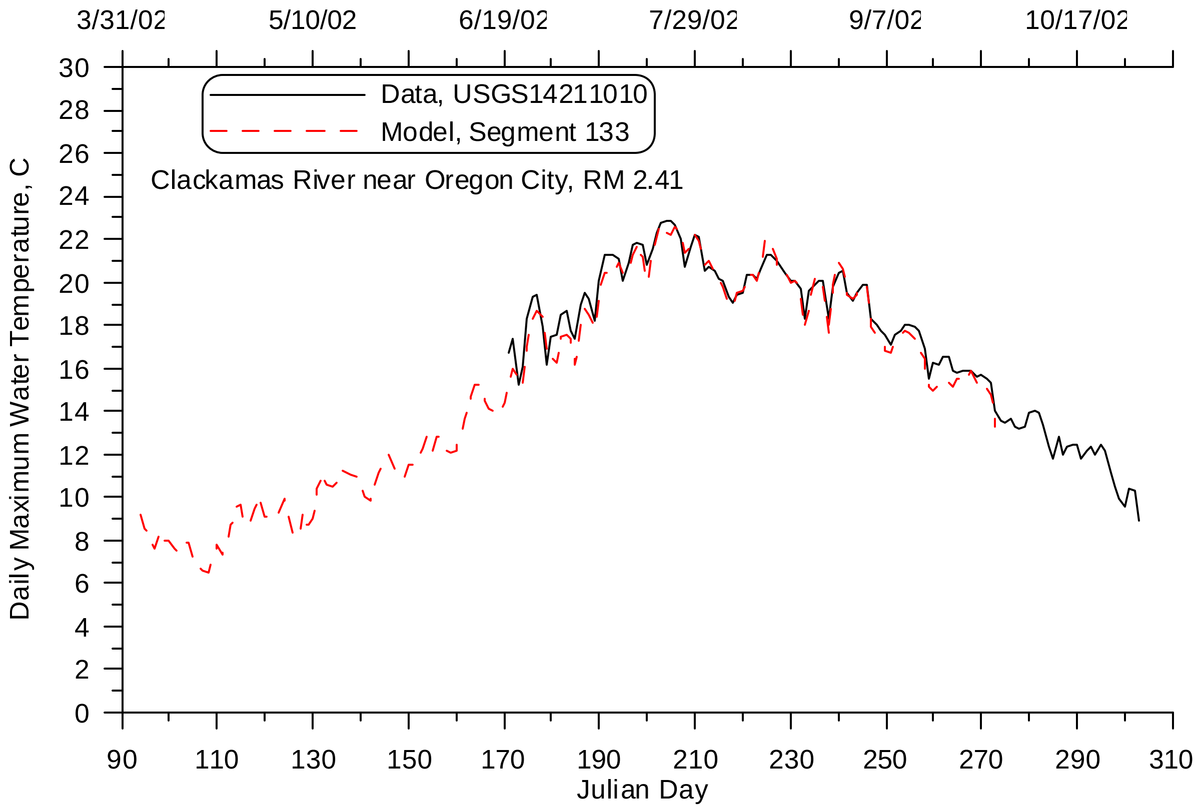

Figure 299: Clackamas River at Oregon City model-data daily maximum temperature comparison, 2002

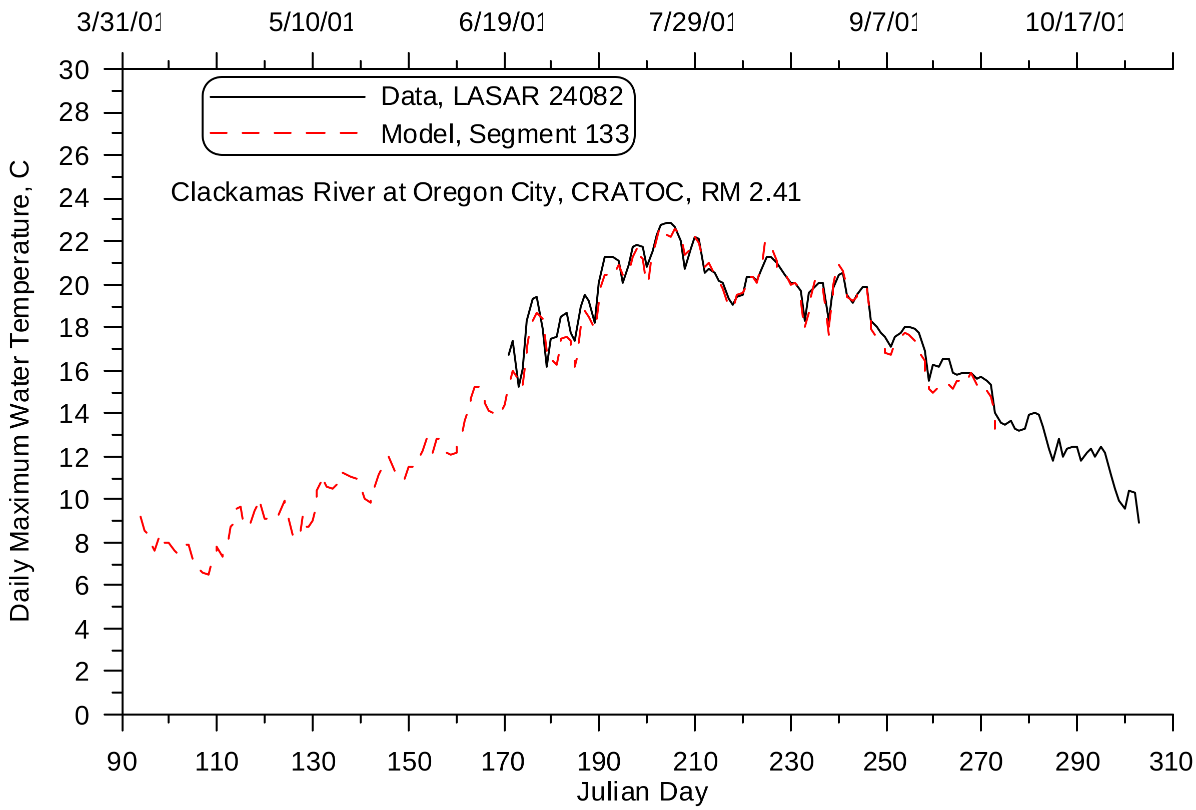

Figure 300: Clackamas River at Oregon City model-data daily maximum temperature comparison, 2002

Long Tom River

Introduction

The Long Tom River model calibration was performed by calibrating hydrodynamics (water level and flow), followed channel widths, dye studies and time of travel studies, and then water temperature. Figure 301 shows the model domain from Fern Ridge Reservoir downstream to the river's confluence with the Upper Willamette River. The model calibration period for 2001 was from May 30 to October 15 and for 2002 from April 1 to October 31.

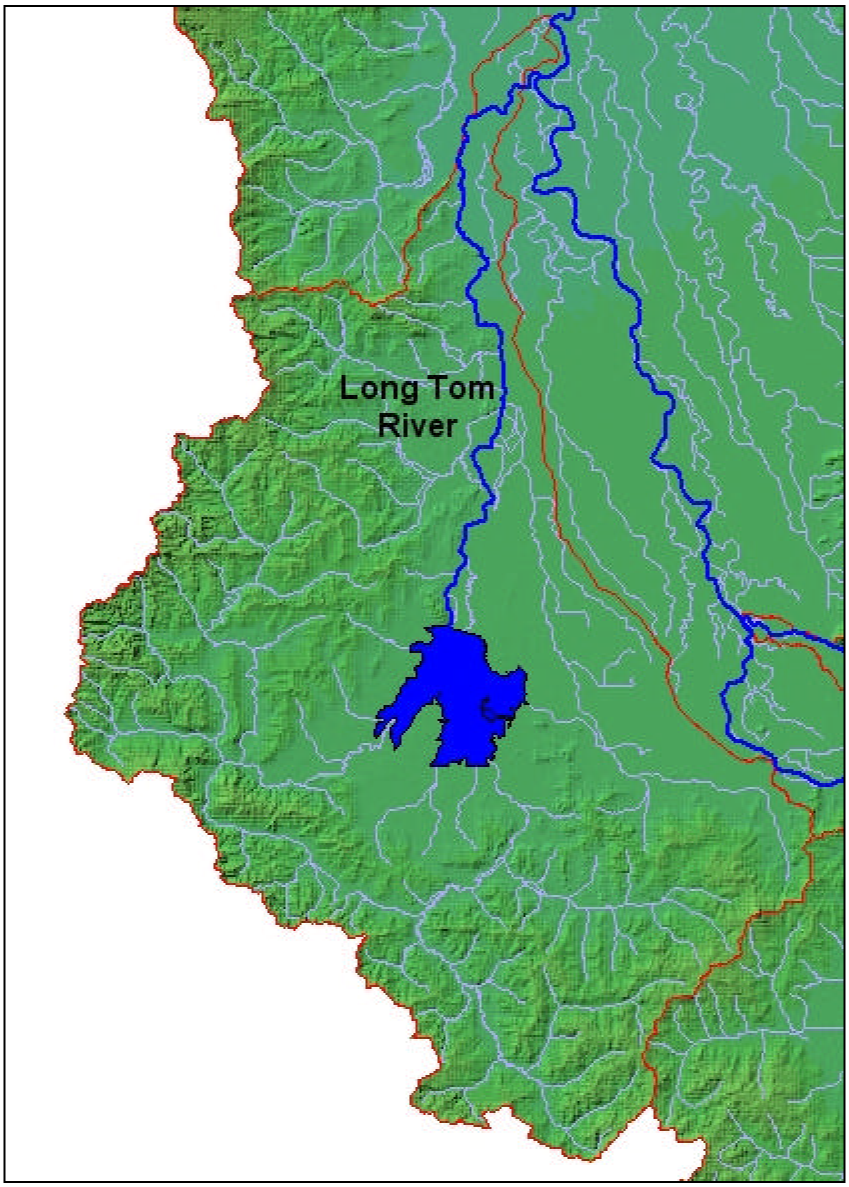

Figure 301: Long Tom River model region

Hydrodynamics

Hydrodynamics were first calibrated using water level and flow data. Model adjustments were then made to calibrate the model for time of travel and dye studies and wetted width river channel data. The calibration parameters used were Manning's friction factor, adjustments to the channel slope and the channel widths since there was limited bathymetric data for the river.

Flow and Water Surface Elevation

The Long Tom River basin has two gage stations with continuous flow and water surface elevation data for calibrating the model. Figure 302 shows a map of the basin with the gage site locations and Table 42 lists the gage sites, their RM, and corresponding model segment.

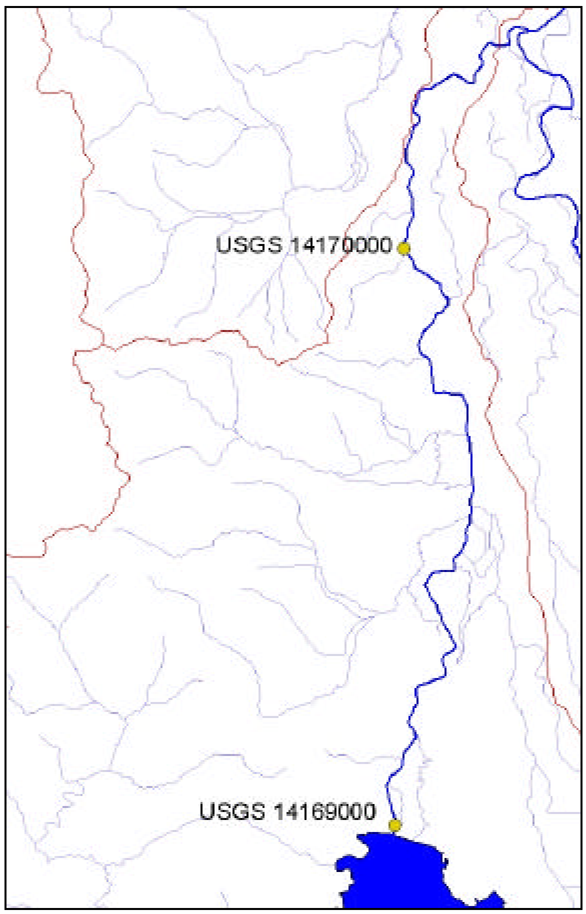

Figure 302: Long Tom River hydrodynamics calibration site locations

Table 42: Long Tom River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14169000	Long Tom River near Alvadore, OR	23.47	2	Q & WL
USGS 14170000	Long Tom River at Monroe, OR	6.86	134	Q & WL

Tributary data were unavailable for the Long Tom River. Tributary inflows were modeled by adding distributed tributaries. Flow rates were determined by balancing flows using gaging station data. There are several diversions along the Long Tom River, the largest of which diverts water around Ferguson Reservoir. A portion of the flow, dependent on how much is used for irrigation, is returned to the river below Ferguson Bridge. The model simulates this diversion channel around Ferguson Reservoir.

Year 2001

Model-data error statistics for the 2001 Long Tom River hydrodynamic calibration are listed in Table 43. Figure 303 through Figure 306 show model and data comparisons of water level and flow. These figures show the model is doing well simulating both the flow and surface elevation at both sites in 2001. Both gaging stations were upstream of dams so calibrating for water level required setting an appropriate weir height.

Table 43: Long Tom River hydrodynamic calibration model-data error statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14169000	23.47	2	5808	0.00	0.00	0.01
USGS 14170000	6.86	134	5607	0.00	0.07	0.09
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14169000	23.47	2	5808	-0.01	0.02	0.02
USGS 14170000	6.86	134	5607	-0.03	0.03	0.03

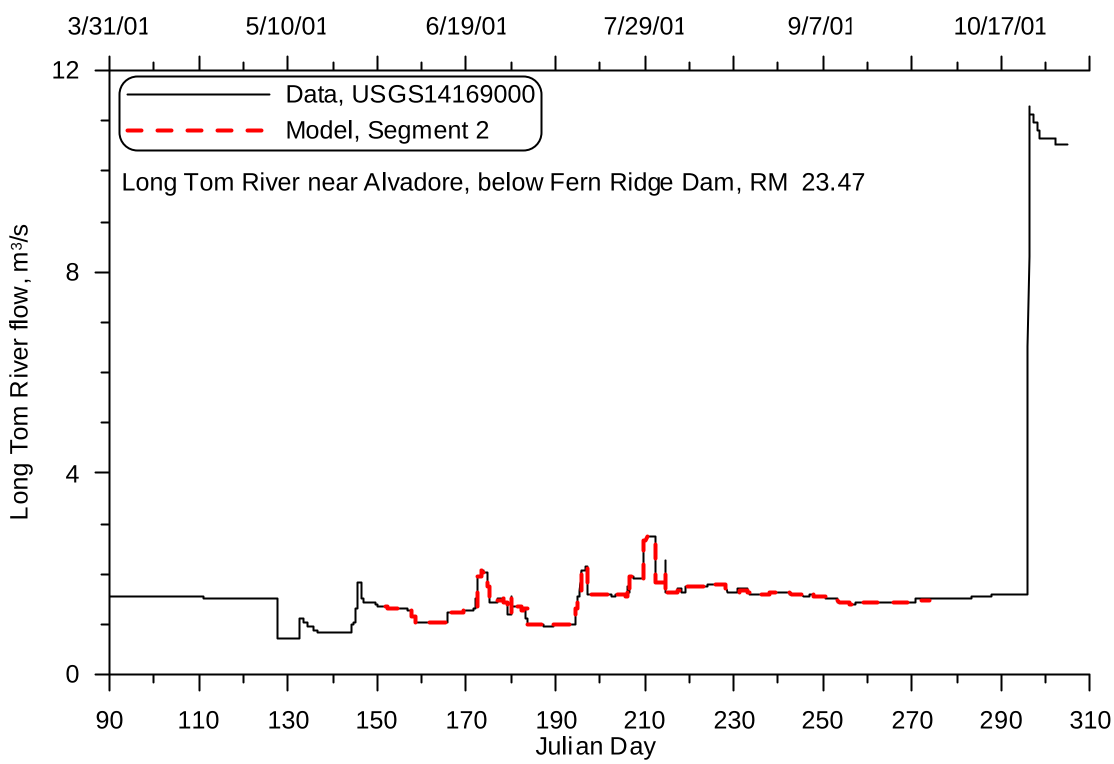

Figure 303: Long Tom River near Alvadore model-data flow comparison, 2001

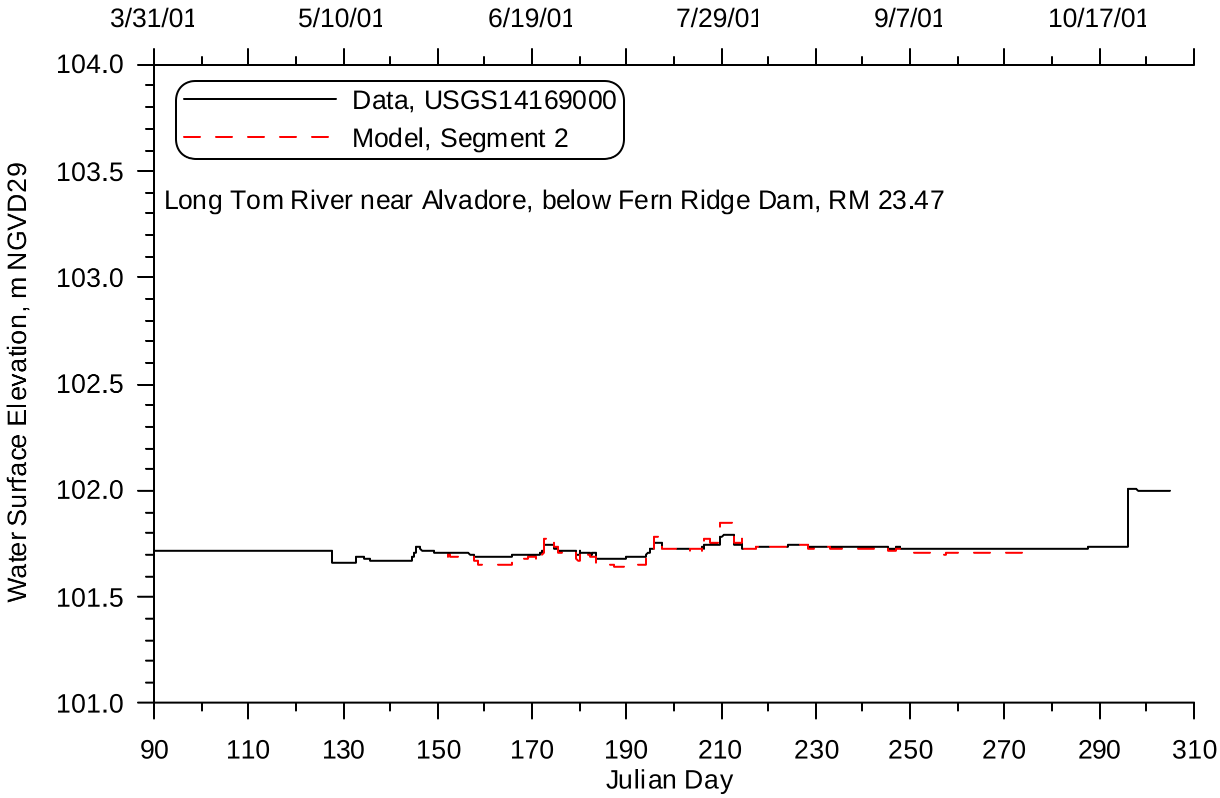

Figure 304: Long Tom River near Alvadore model-data water level comparison, 2001

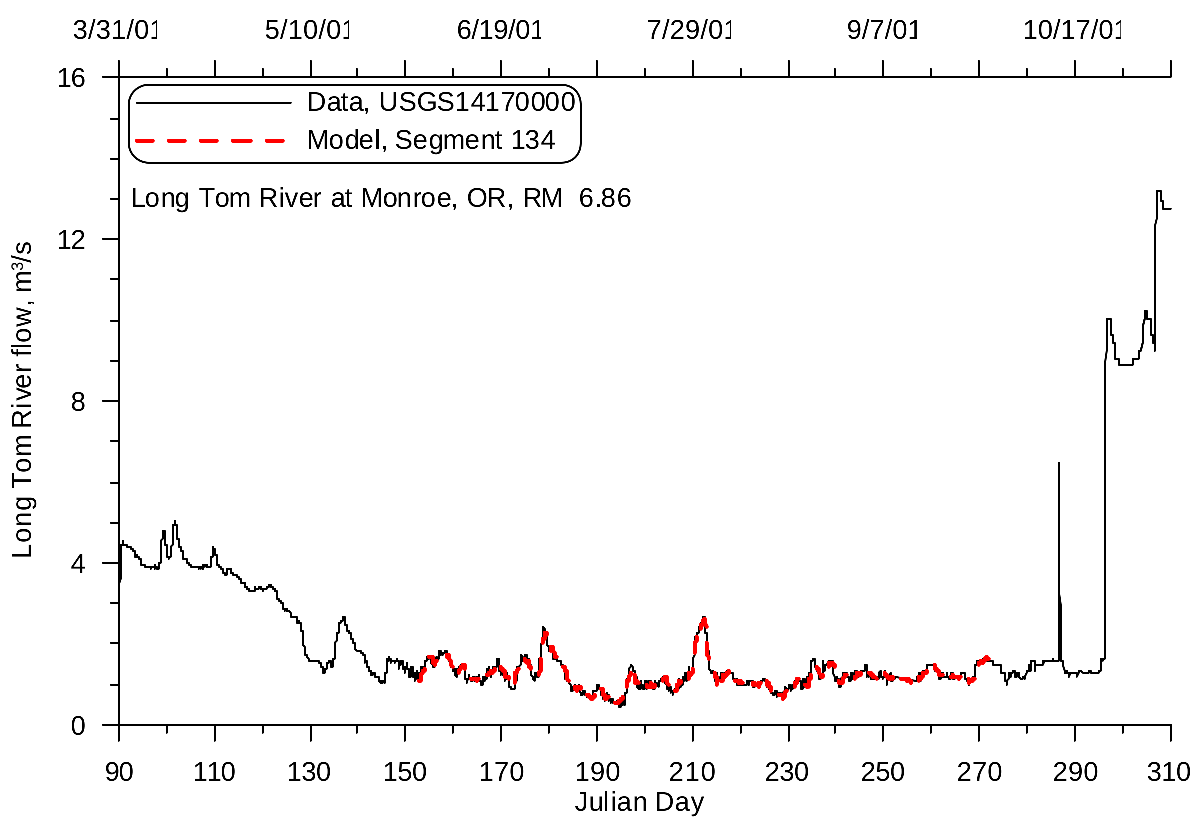

Figure 305: Long Tom River at Monroe model-data flow comparison, 2001

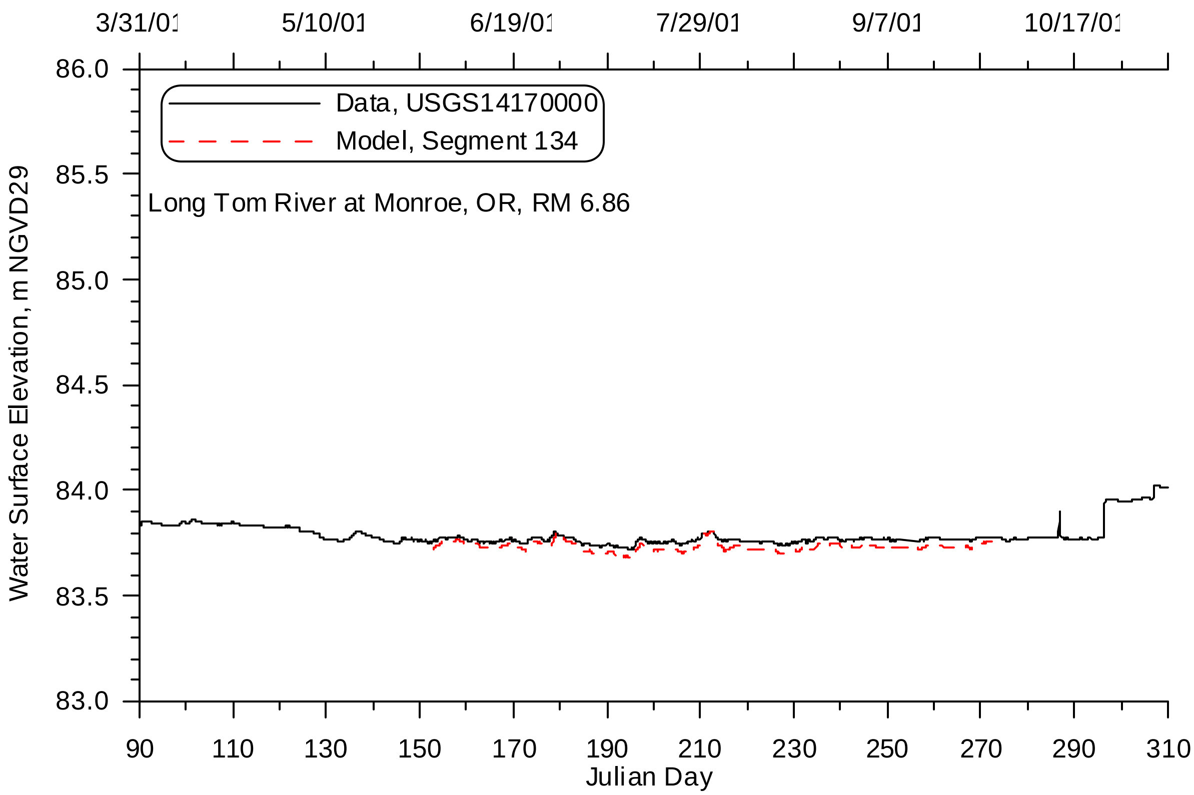

Figure 306: Long Tom River at Monroe model-data water level comparison, 2001

Year 2002

Table 44 shows water level and flow model-data error statistics for the Long Tom River 2002 model. Figure 307 through Figure 310 plot model-data comparisons of water level and flow. The time series comparison plots show there is good model-data agreement at both sites. In late May there was slightly less agreement with water level at the upstream site due to a flow peak but this was brief and may be due to lack bathymetric data. The gaging stations were upstream of dams and calibrating water level required setting the appropriate dam height.

Table 44: Long Tom River hydrodynamic calibration model-data error statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14169000	23.47	2	8688	0.00	0.01	0.08
USGS 14170000	6.86	134	8688	0.02	0.13	0.31
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14169000	23.47	2	8688	0.01	0.02	0.07
USGS 14170000	6.86	134	8688	0.00	0.03	0.04

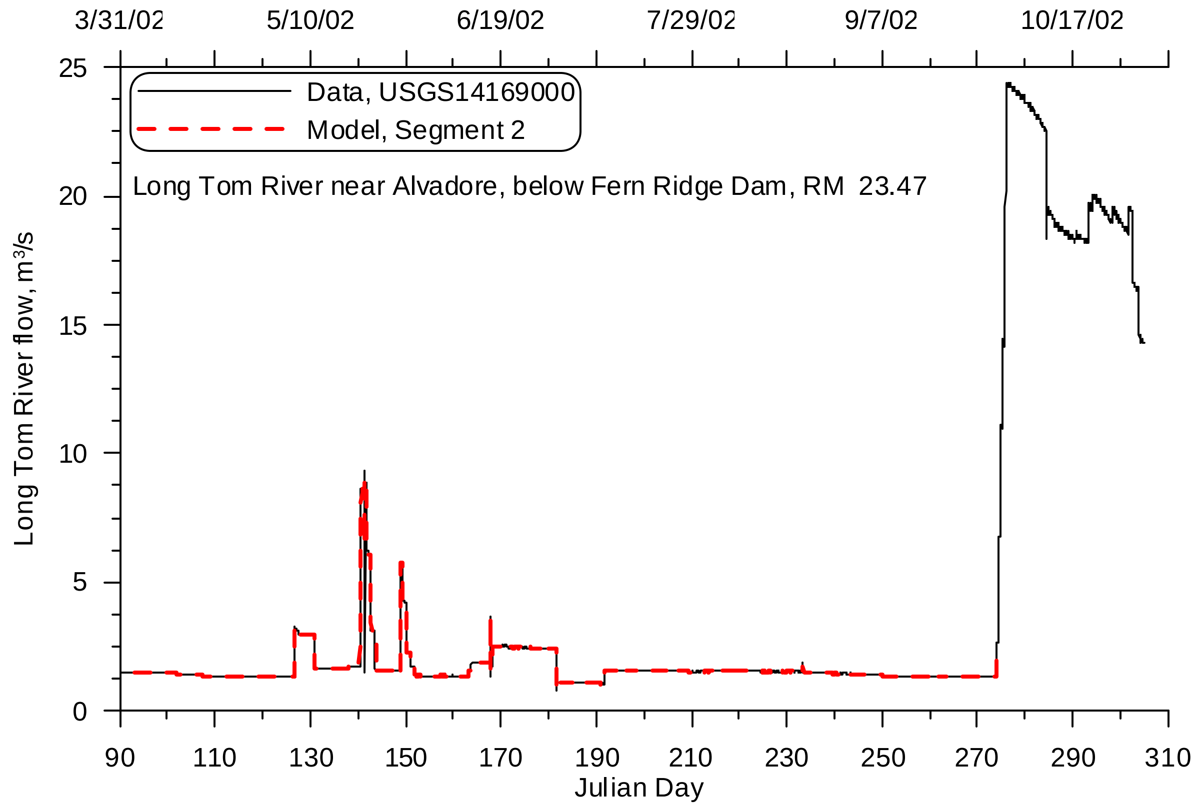

Figure 307: Long Tom River near Alvadore model-data flow comparison, 2002

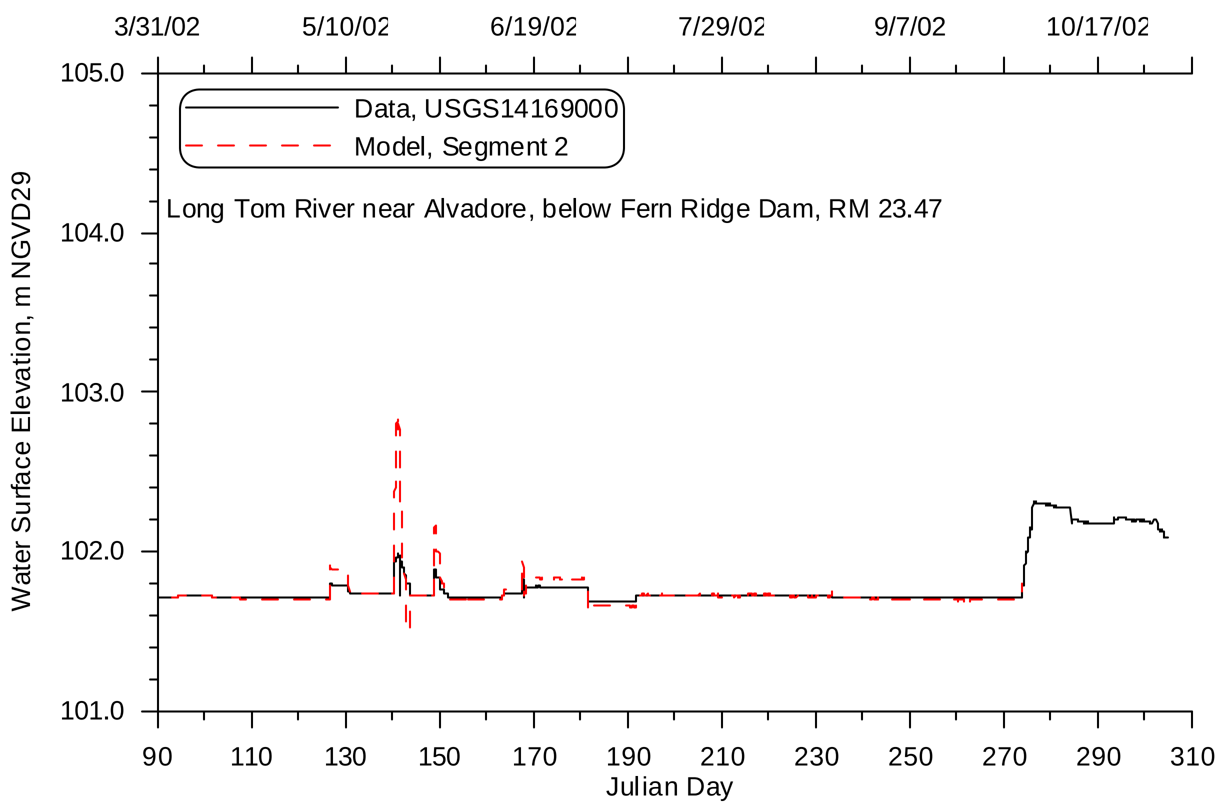

Figure 308: Long Tom River near Alvadore model-data water level comparison, 2002

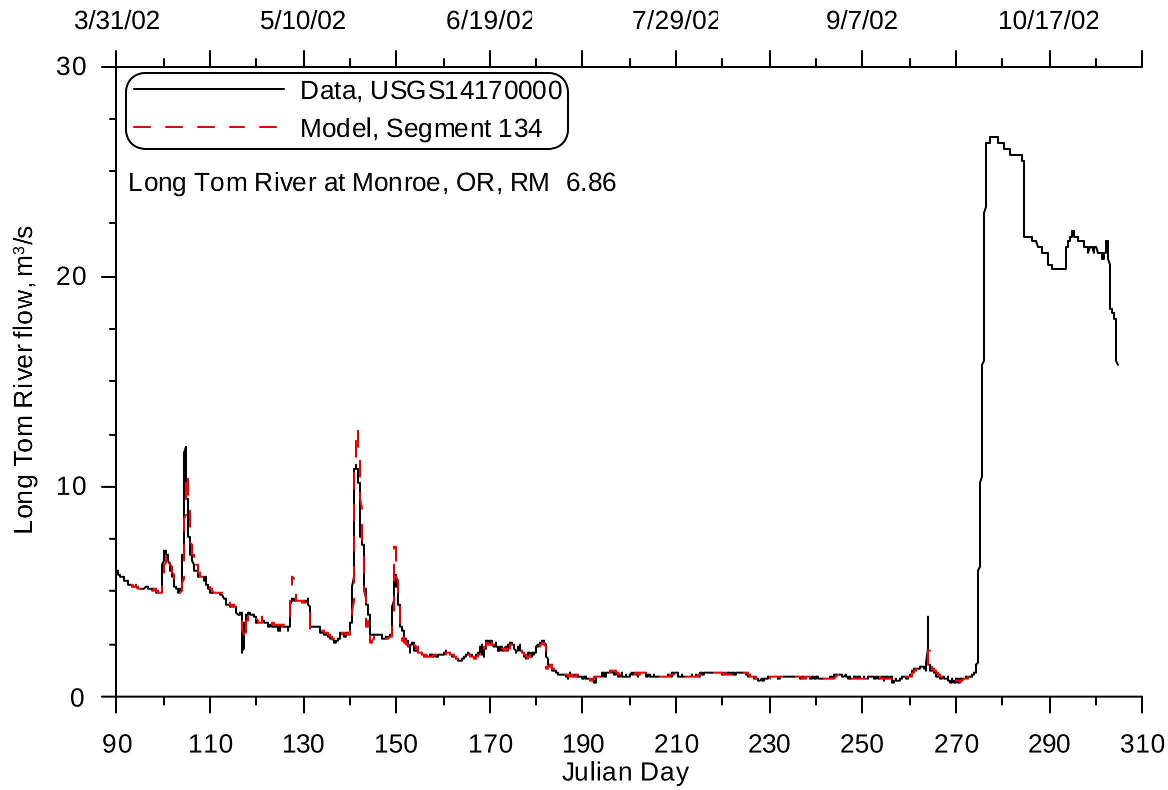

Figure 309: Long Tom River at Monroe model-data flow comparison, 2002

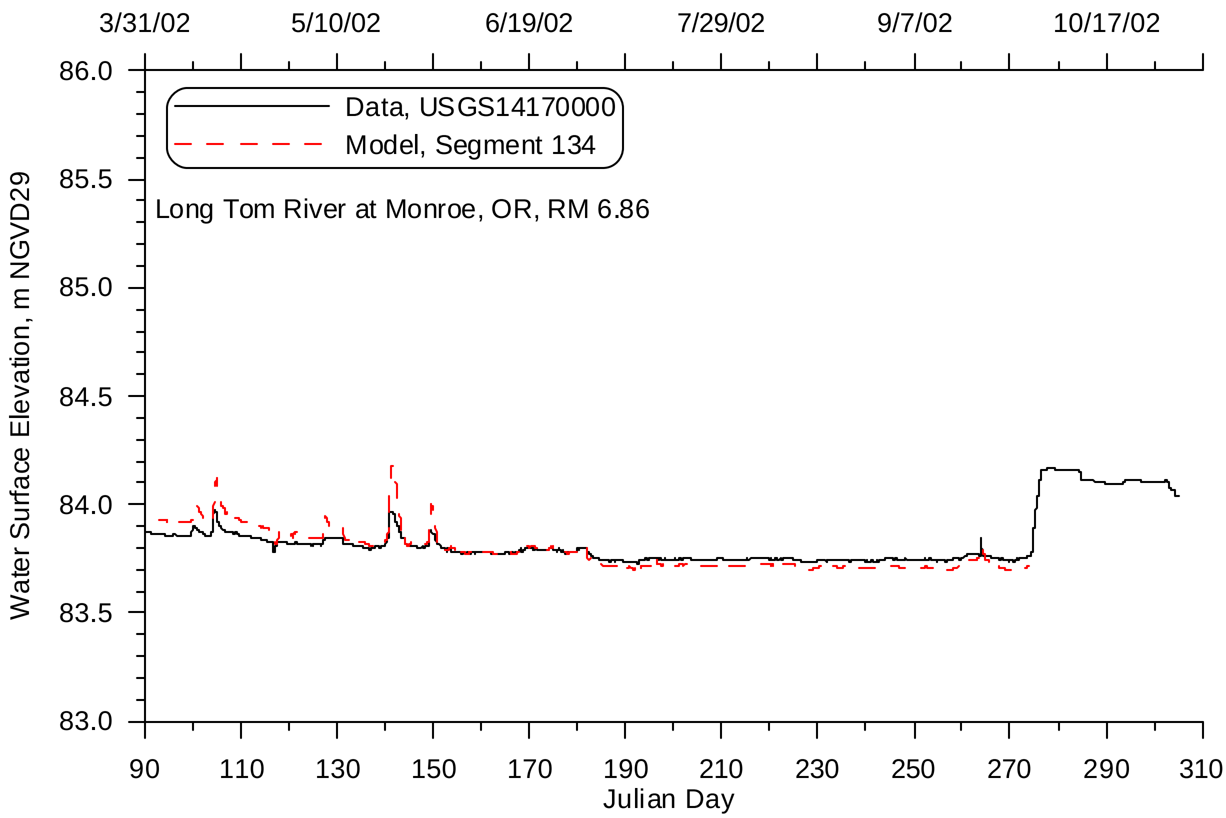

Figure 310: Long Tom River at Monroe model-data water level comparison, 2002

Time of Travel/Dye Studies

Dye studies were conducted by the USGS during May and August of 2002. Dye was released at Alvadore (segment 2), Ferguson Dam (segment 95), and Stroda Ford (segment 115). Concentrations were measured for several days after the initial dye input. Table 45 summarizes the release locations and times of the dye studies.

Table 45: Dye release points for the USGS 2002 Long Tom dye studies.

Dye Release Point	Date	River Mile	Model Segment
Alvadore	05/07/2002, 6:30 am	23.1	2
Ferguson Dam	05/08/2002, 8:00 am	12.05	95
Alvadore	08/20/2002 5:30 am	23.1	2
Stroda Ford	08/19/2002 12:00 pm	9.25	115

Model-data comparisons of the May and August 2002 dye studies are shown in Figure 311 through Figure 314. The dye study plots show there is close model data agreement at the furthest upstream site in May and less agreement at the downstream site. The August dye study results show a similar pattern with relatively good agreement upstream and less agreement at the downstream site. Overall the results are reasonable considering the lack of bathymetric data and the need to balance channel shape to meet hydrodynamic and temperature calibrations. The main calibration tool was varying the heights of several low rock dams that exist in the Long Tom River.

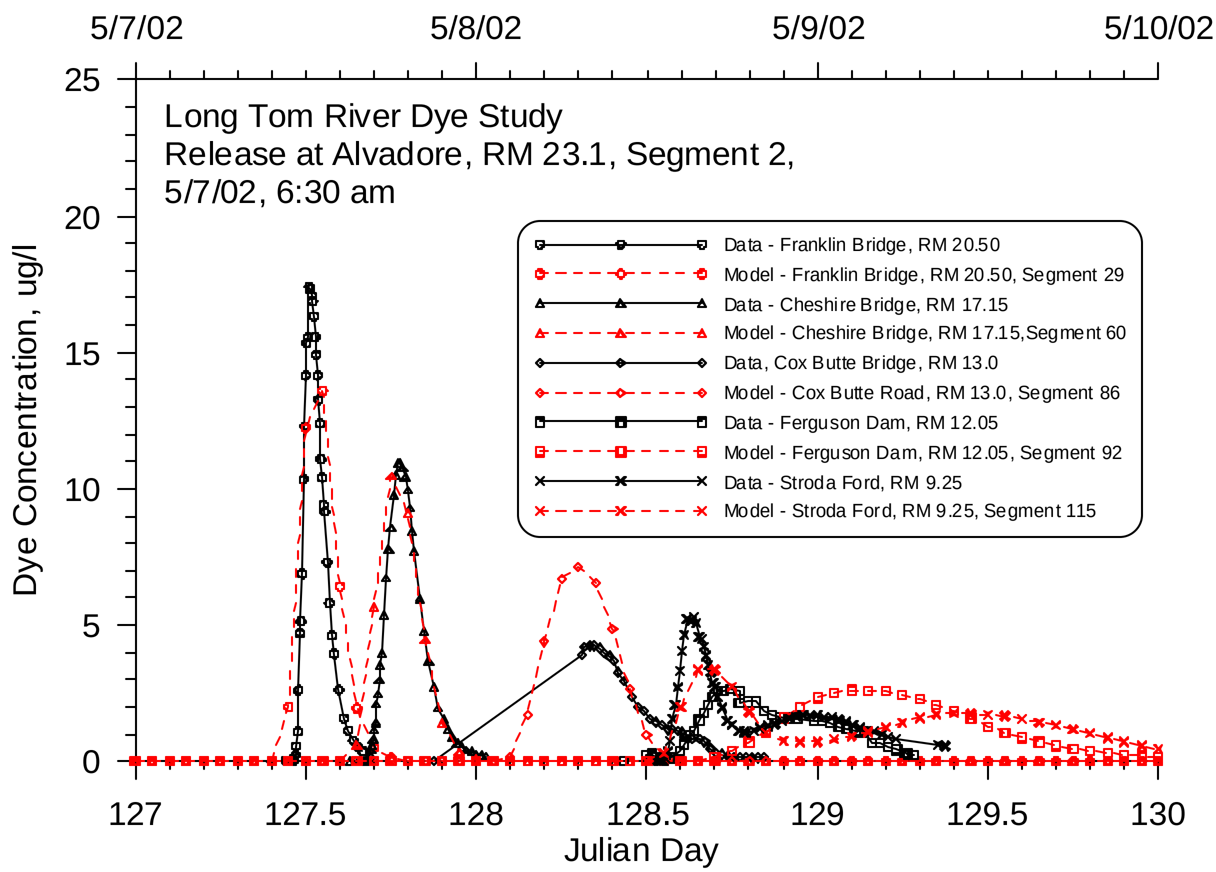

Figure 311: Model-data comparison of dye concentration for the May 2002 Long Tom River dye study, release at Alvadore.

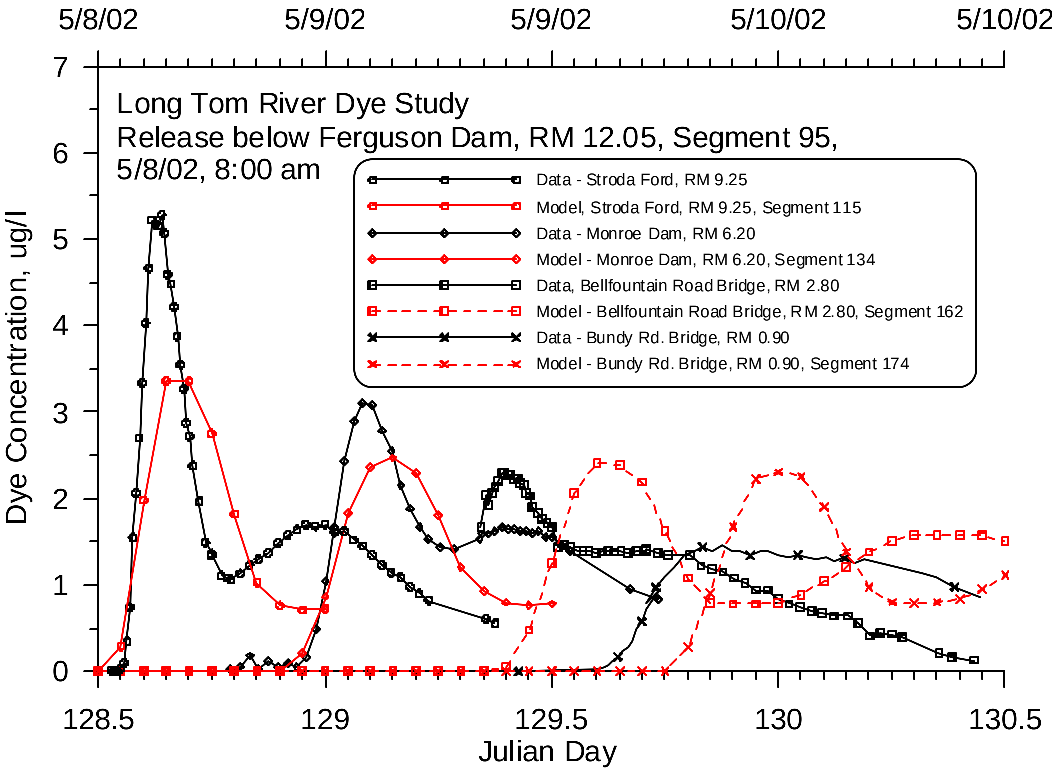

Figure 312: Model-data comparison of dye concentration for the May 2002 Long Tom River dye study, release below Ferguson Dam.

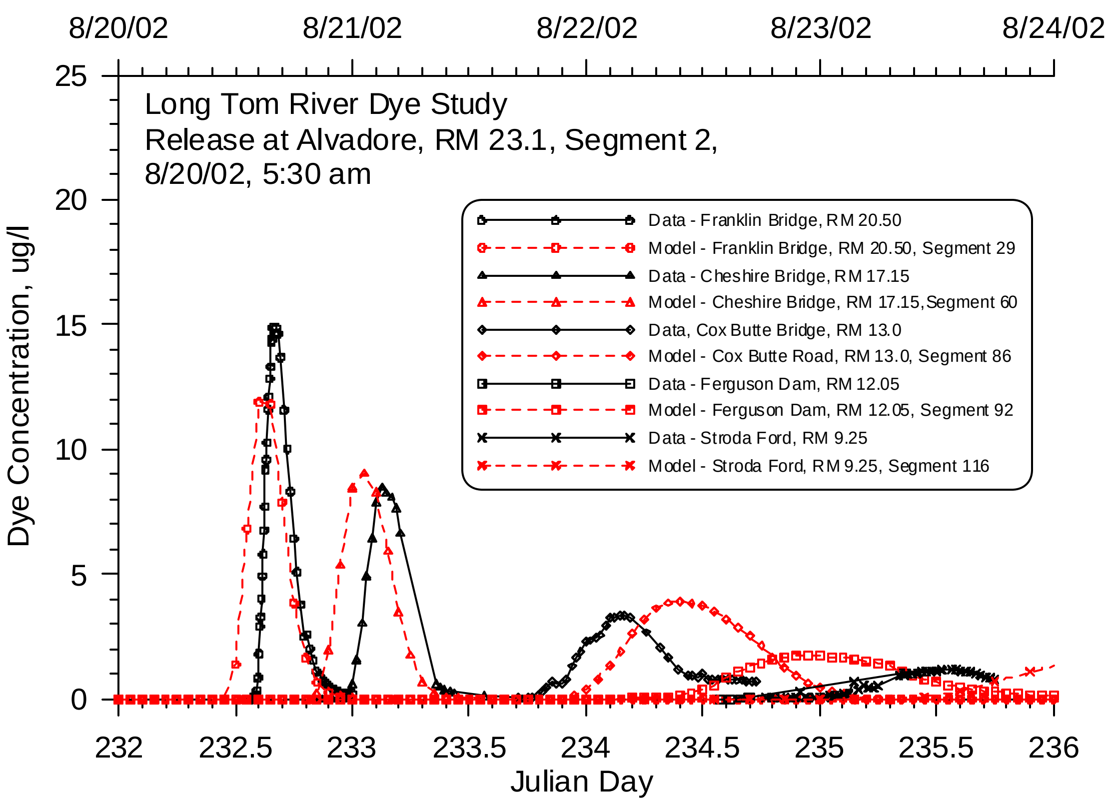

Figure 313: Model-data comparison of dye concentration for the August 2002 Long Tom River dye study, release at Alvadore.

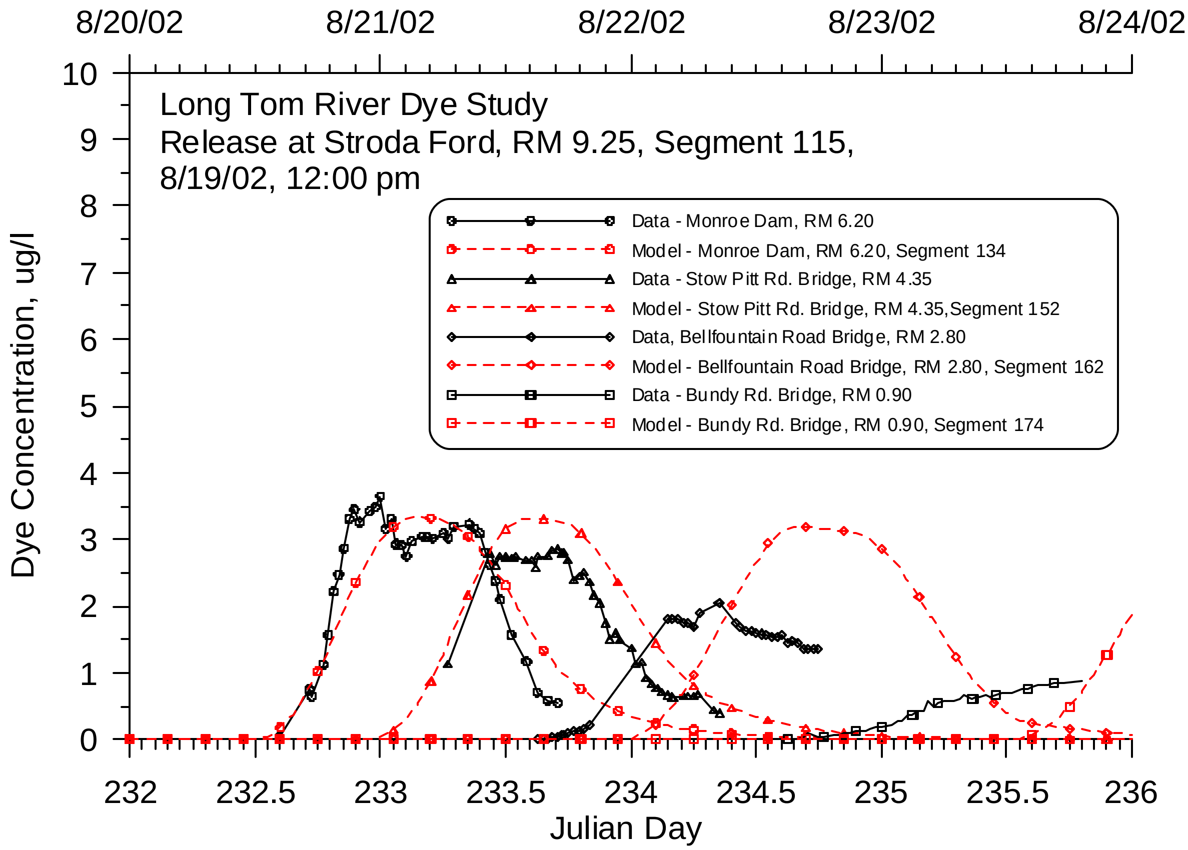

Figure 314: Model-data comparison of dye concentration for the August 2002 Long Tom River dye study, release at Stroda Ford.

Water Temperature

Water temperature was calibrated using continuous temperature data recorded every half hour or hour at several locations. Model-data comparisons were made both at small time scales and at large time scales over the simulation period to ensure diurnal fluctuations were simulated accurately. Calibration parameters included adjusting the Manning's friction factor, channel widths, wind sheltering, evaporation, and sediment temperatures. Vegetative and topographic shade characteristics were not adjusted since the model input was developed using a detailed GIS analysis.

The Long Tom River has five sites where continuous temperatures were recorded for calibrating the model. Figure 315 shows a map of the basin with the gage site locations and Table 46 shows a list of the gage sites with RM and corresponding model segment.

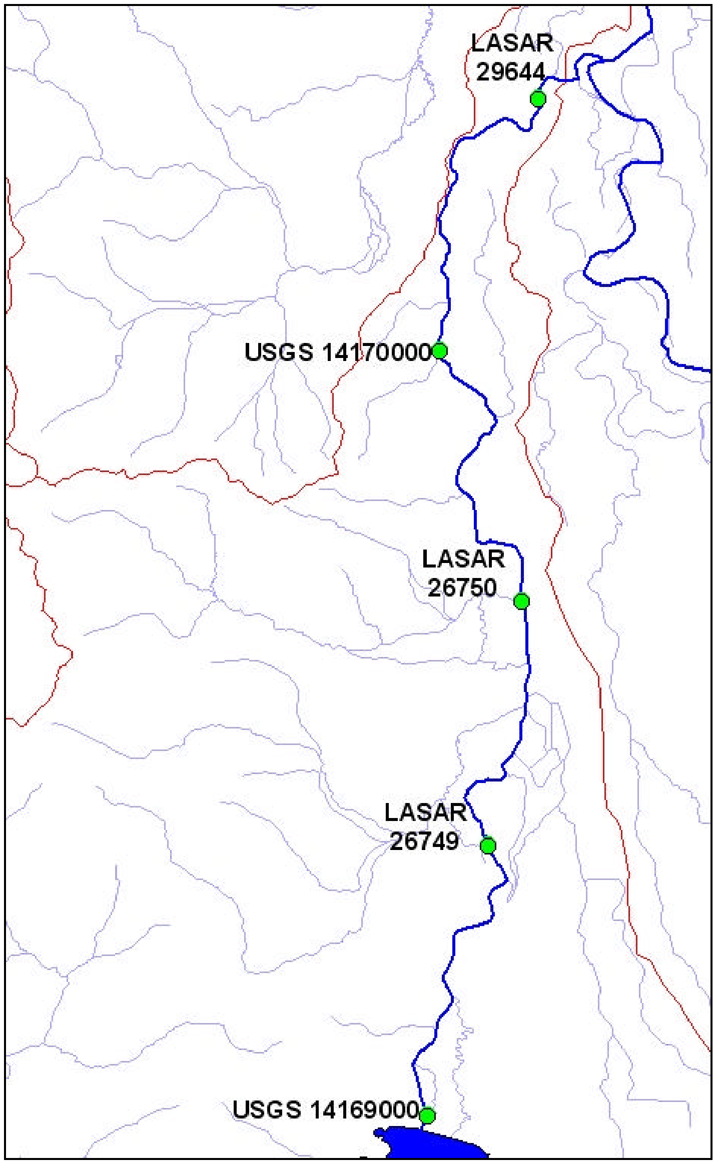

Figure 315: Long Tom River water temperature calibration site locations

Table 46: Long Tom River water temperature calibration sites

Site ID	Site Description	RM	Model Segment
USGS 14169000	Long Tom River near Alvadore, OR	23.47	2
LASAR 26749	Long Tom River at RM 19.8	17.75	55
LASAR 26750	Long Tom River at RM 12.3	12.71	95
USGS14170000	Long Tom River at Monroe, OR	6.86	134
LASAR 29644	Long Tom River near Mouth	0.91	176

The model was calibrated by comparing the continuous temperature data and model results but since the model will be used for running model scenarios examining the daily maximum temperature model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

Table 47 lists model-data error statistics of continuous model temperature predictions for the 2001 Long Tom River model. Model-data time series comparisons of continuous temperature are shown in Figure 316 through Figure 319. The time series plot show the model does reasonably well in predicting both the diurnal temperature swings and the 10-14 day weather patterns. There are brief incidences when the model prediction deviate more from the data but overall results are good. Calibration of temperature required adjusting wind sheltering and some instances, channel width. There were also several low rock dams in the upper section of the river which were simulated as weirs and their heights were varied as a calibration parameter. The Long Tom River is fairly shallow, and adjusting the height of these low dams can significantly affect travel time. Model-data error statistics are 1.07 ^oC or less.

Table 47: Long Tom River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
USGS 14169000	23.47	2	2622	0.00	0.03	0.04
LASAR 26749	17.75	55	5904	-0.11	0.70	0.86
LASAR 26750	12.71	95	5585	0.36	0.81	1.07
USGS14170000	6.86	134	2616	-0.13	0.68	0.81

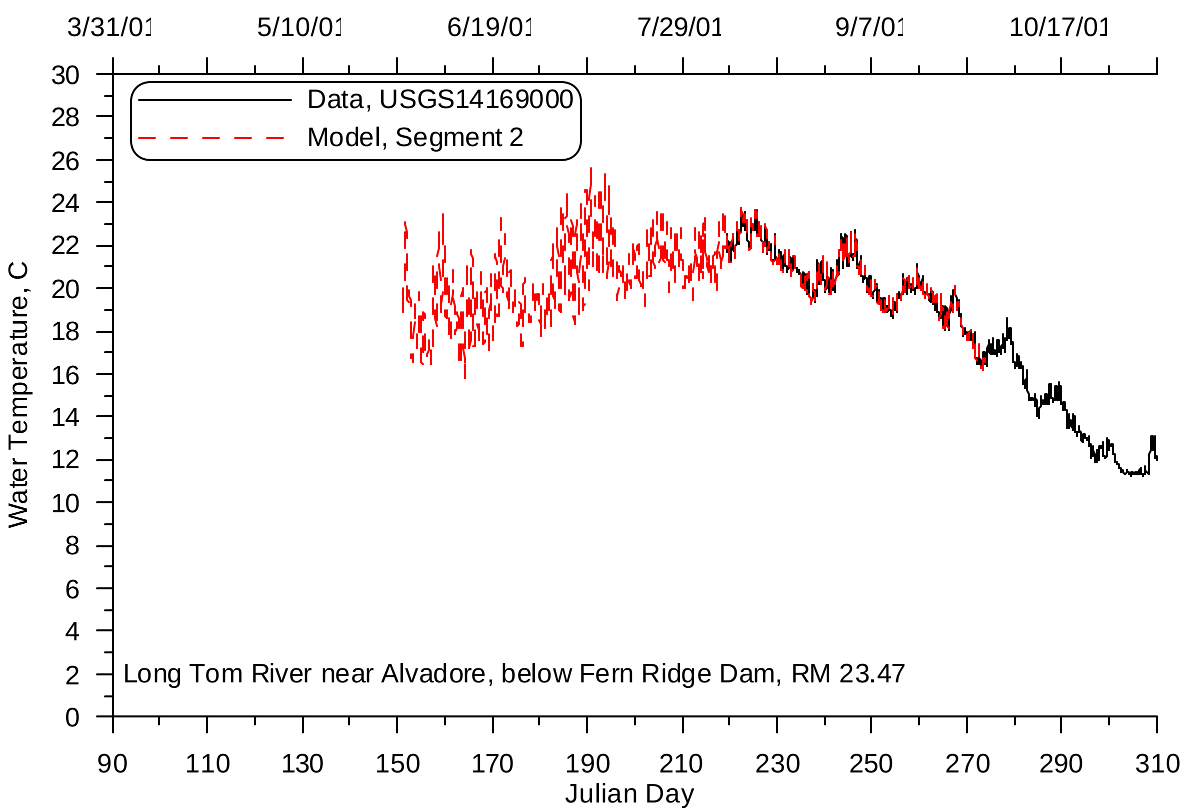

Figure 316: Long Tom River near Alvadore model-data continuous temperature comparison, 2001

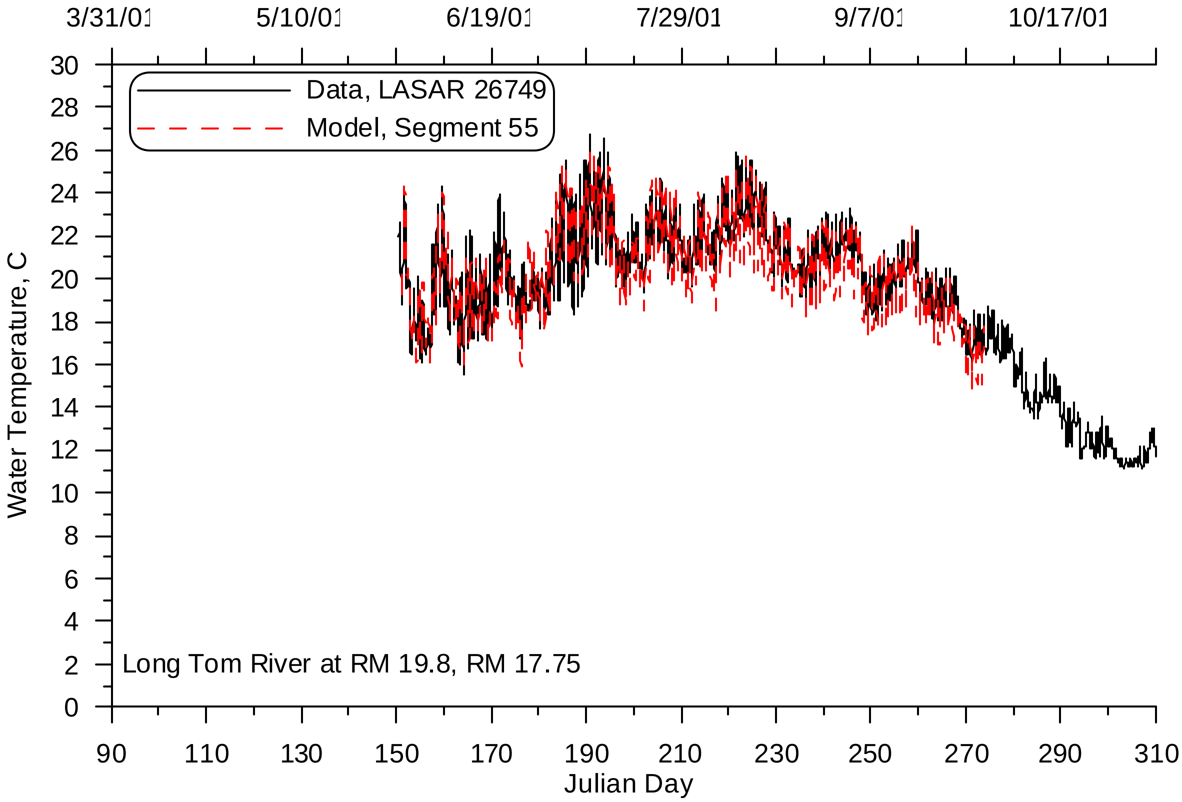

Figure 317: Long Tom River at RM 19.8 model-data continuous temperature comparison, 2001

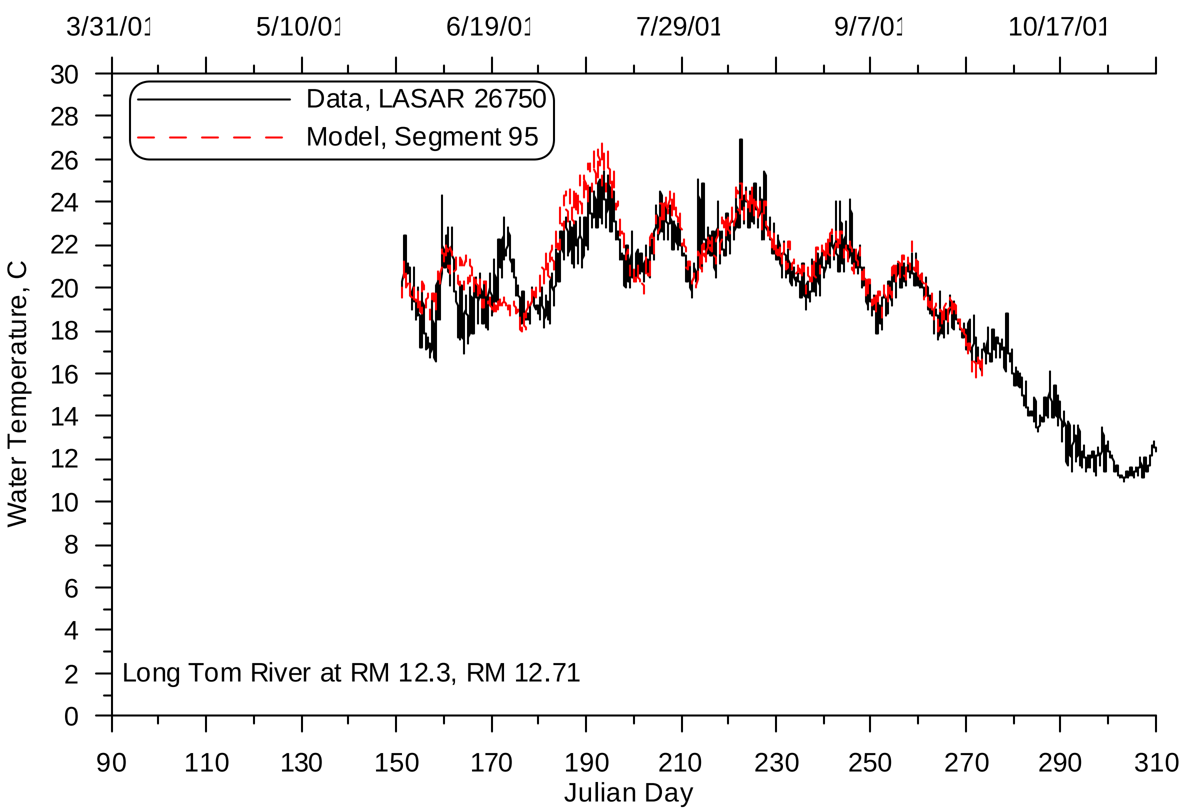

Figure 318: Long Tom River at RM 12.3 model-data continuous temperature comparison, 2001

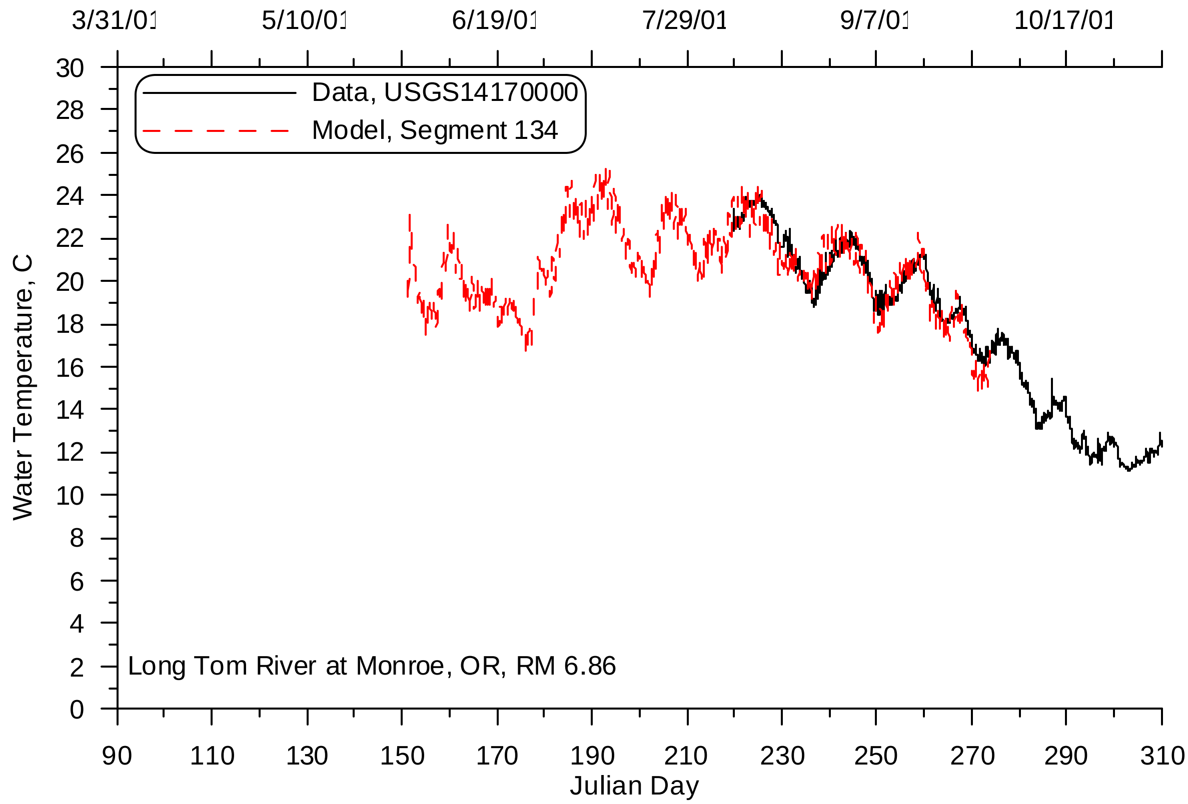

Figure 319: Long Tom River at Monroe model-data continuous temperature comparison, 2001

Year 2002

Model-data error statistics of continuous temperature for the 2002 Long Tom River model are shown in Table 48. Figure 320 through Figure 324 show model-data time series comparisons of continuous temperature. Similar to 2001, the model results track the diurnal and weather pattern influenced temperature changes when compared to data. Model-data error statistics are 1.16 ^{o}C or less.

Table 48: Long Tom River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14169000	23.47	2	8784	0.00	0.04	0.05
LASAR 26749	17.75	55	5922	-0.40	0.74	0.90
LASAR 26750	12.71	95	5844	0.13	0.60	0.77
USGS14170000	6.86	134	8688	-0.40	0.68	0.83
LASAR 29644	0.91	176	5882	-0.26	0.94	1.16

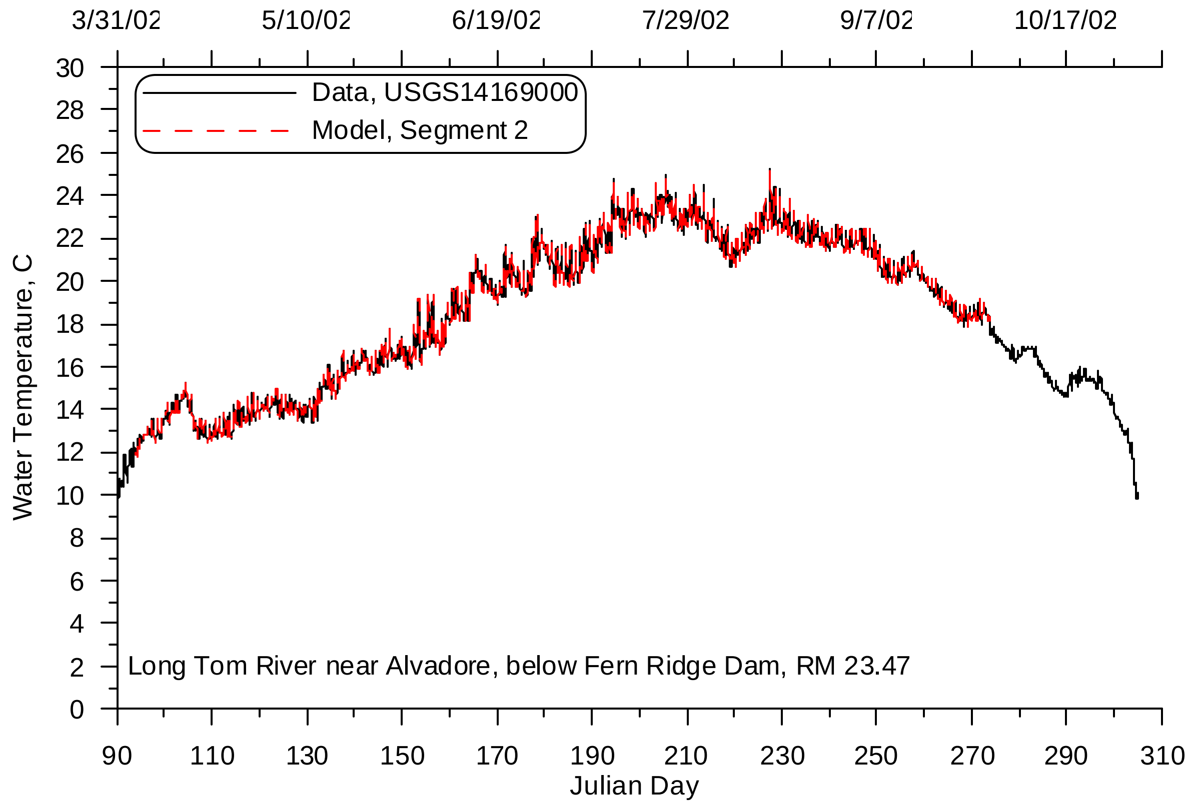

Figure 320: Long Tom River near Alvadore model-data continuous temperature comparison, 2002

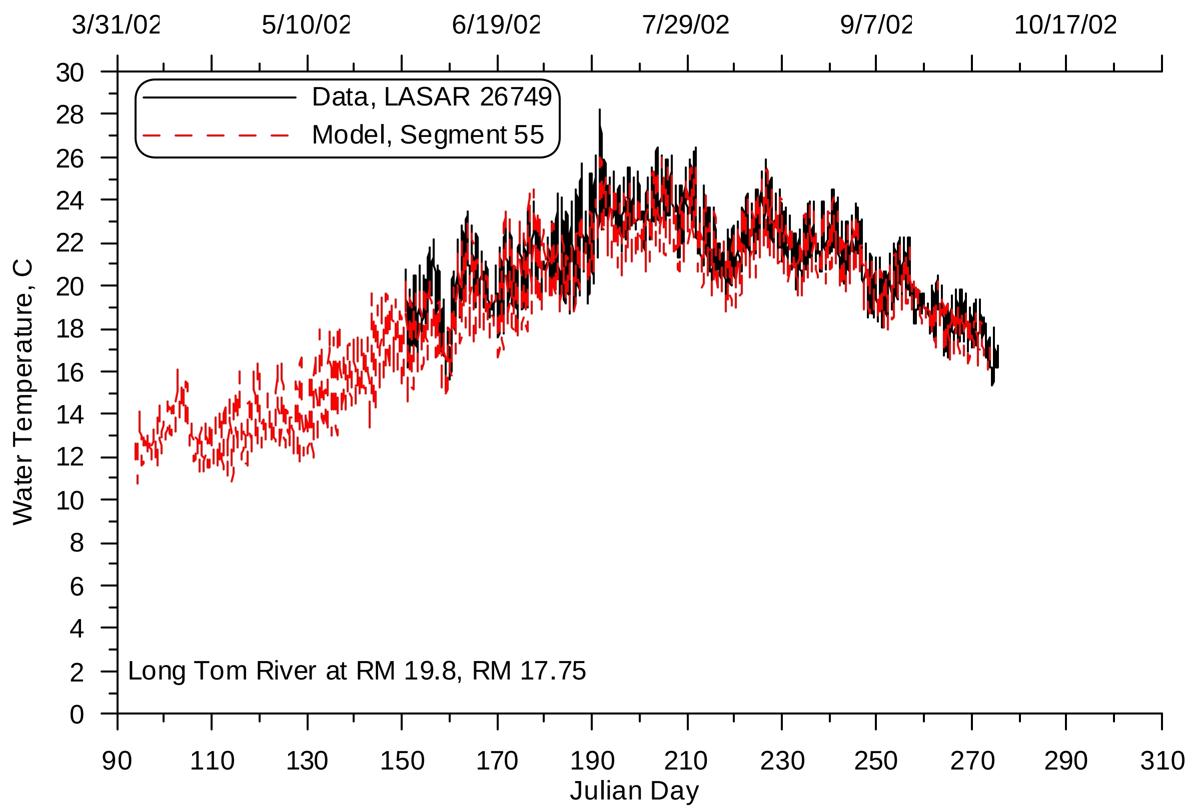

Figure 321: Long Tom River at RM 19.8 model-data continuous temperature comparison, 2002

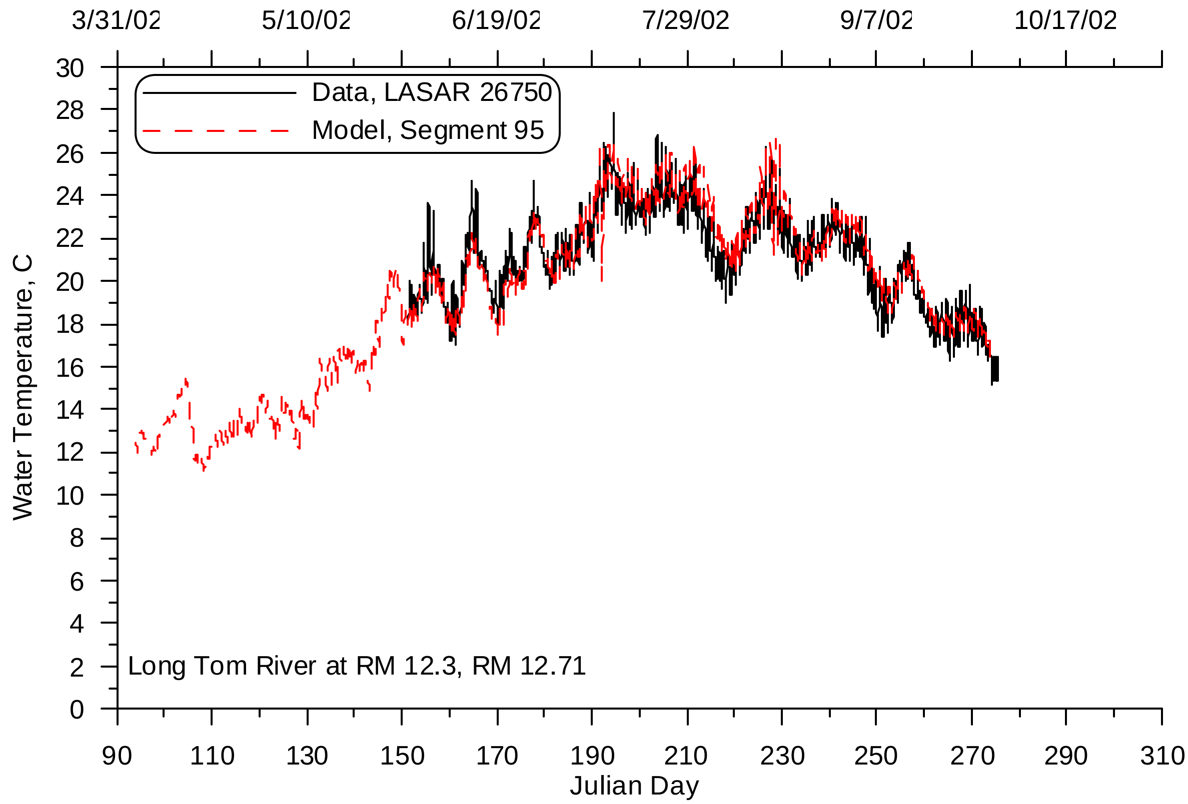

Figure 322: Long Tom River at RM 12.3 model-data continuous temperature comparison, 2002

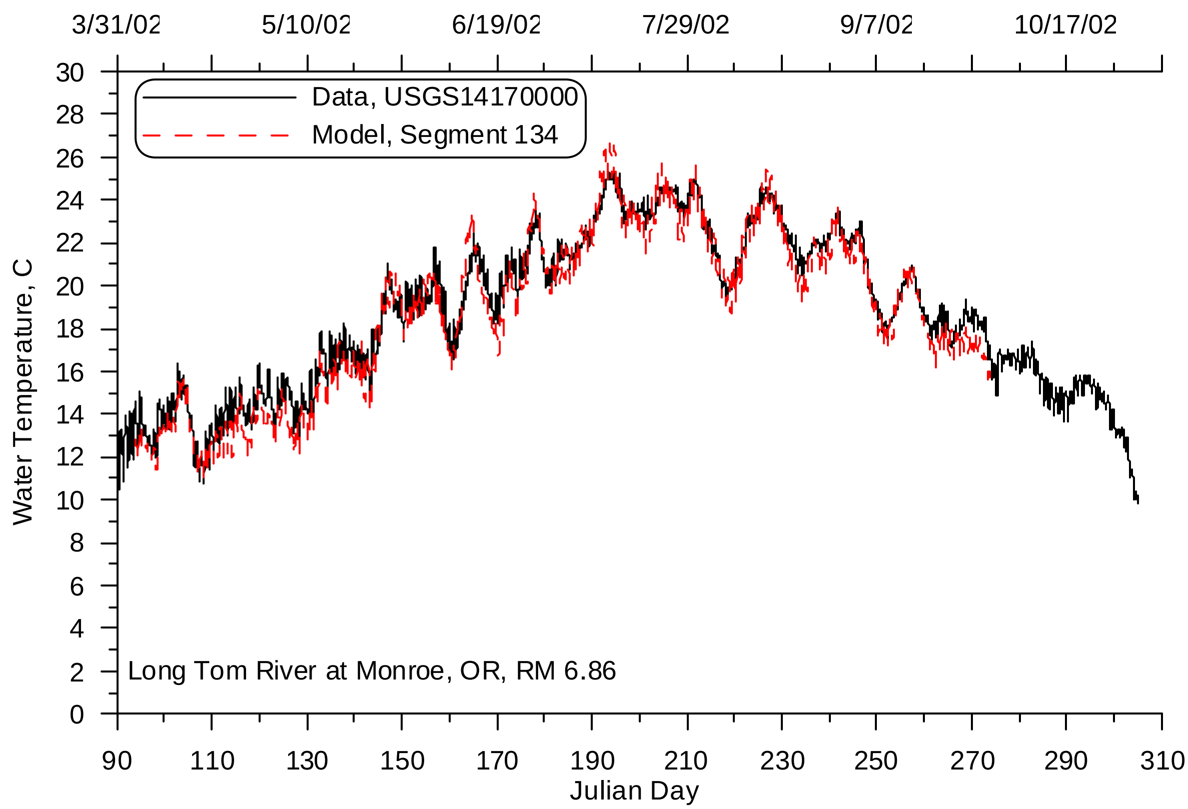

Figure 323: Long Tom River at Monroe model-data continuous temperature comparison, 2002

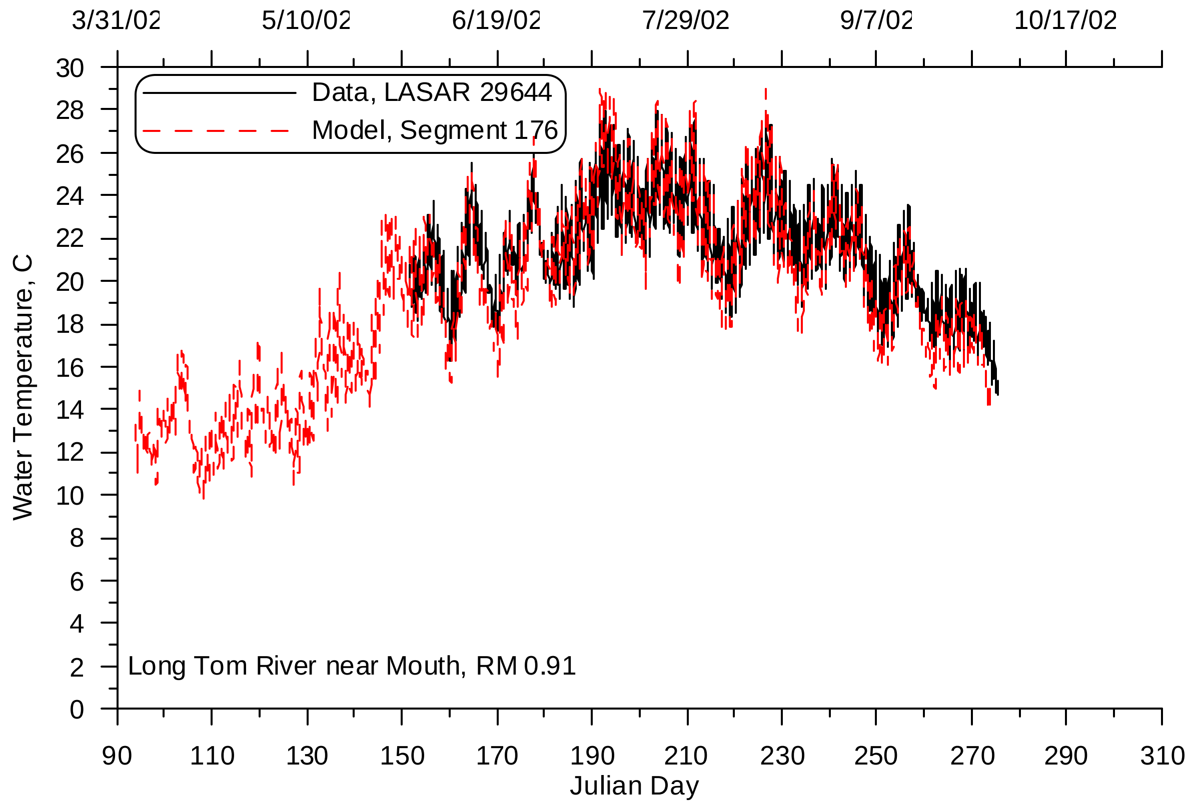

Figure 324: Long Tom River near mouth model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

<u>Year 2001</u>

Model-data error statistics for daily maximum temperature for the 2001 Long Tom River model are shown in Table 49. Time series comparisons are provided in Figure 325 through Figure 328. The time series figures show the model is doing well simulating the daily maximum temperatures compared to data with a slightly larger deviation between the two in later June and early July.

Table 49: Long Tom River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14169000	23.47	2	56	0.02	0.05	0.08
LASAR 26749	17.75	55	123	-0.19	0.61	0.80
LASAR 26750	12.71	95	123	-0.06	0.85	1.16
USGS14170000	6.86	134	56	0.09	0.59	0.69

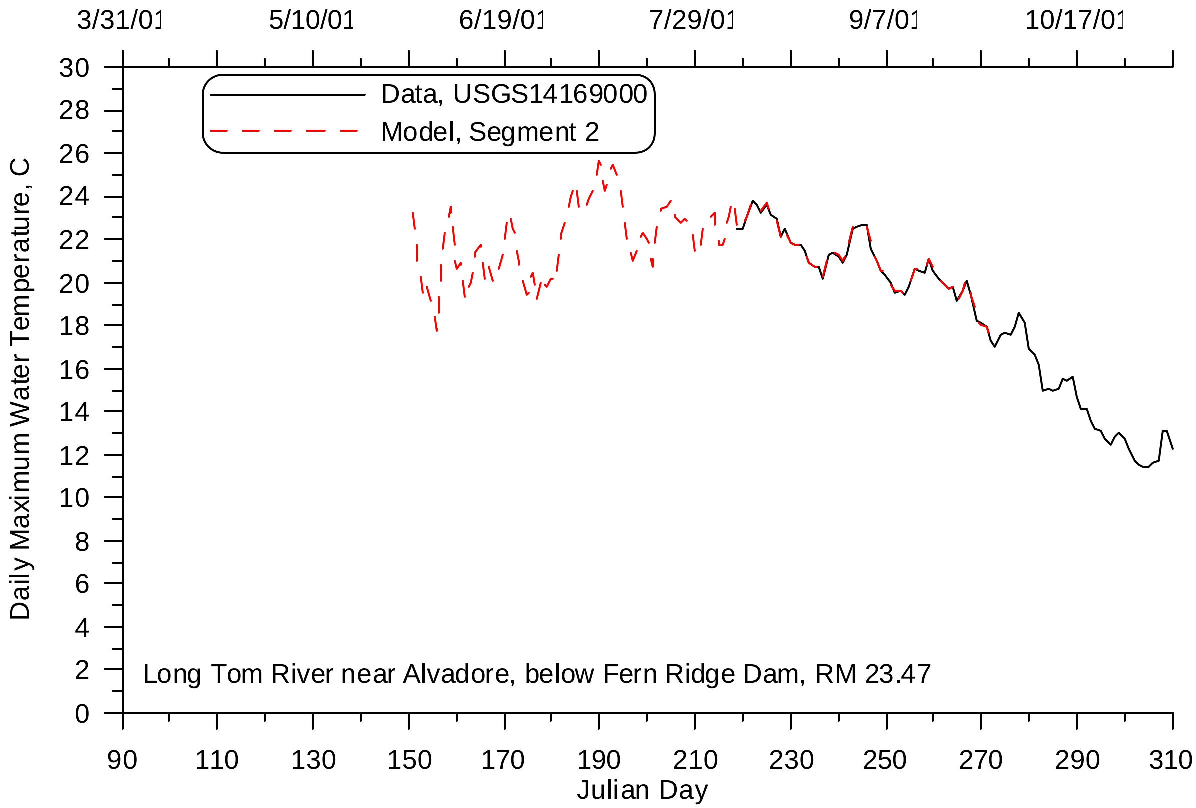

Figure 325: Long Tom River near Alvadore model-data daily maximum temperature comparison, 2001

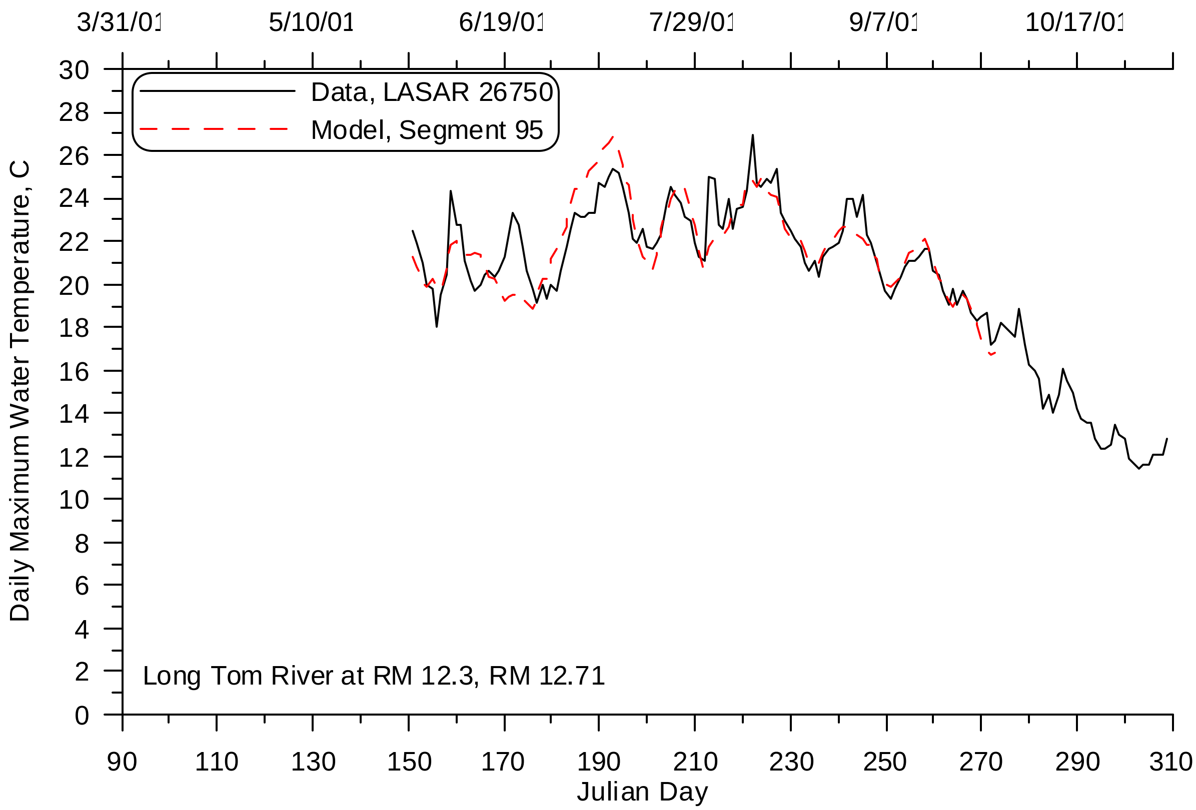

Figure 326: Long Tom River at RM 19.8 model-data daily maximum temperature comparison, 2001

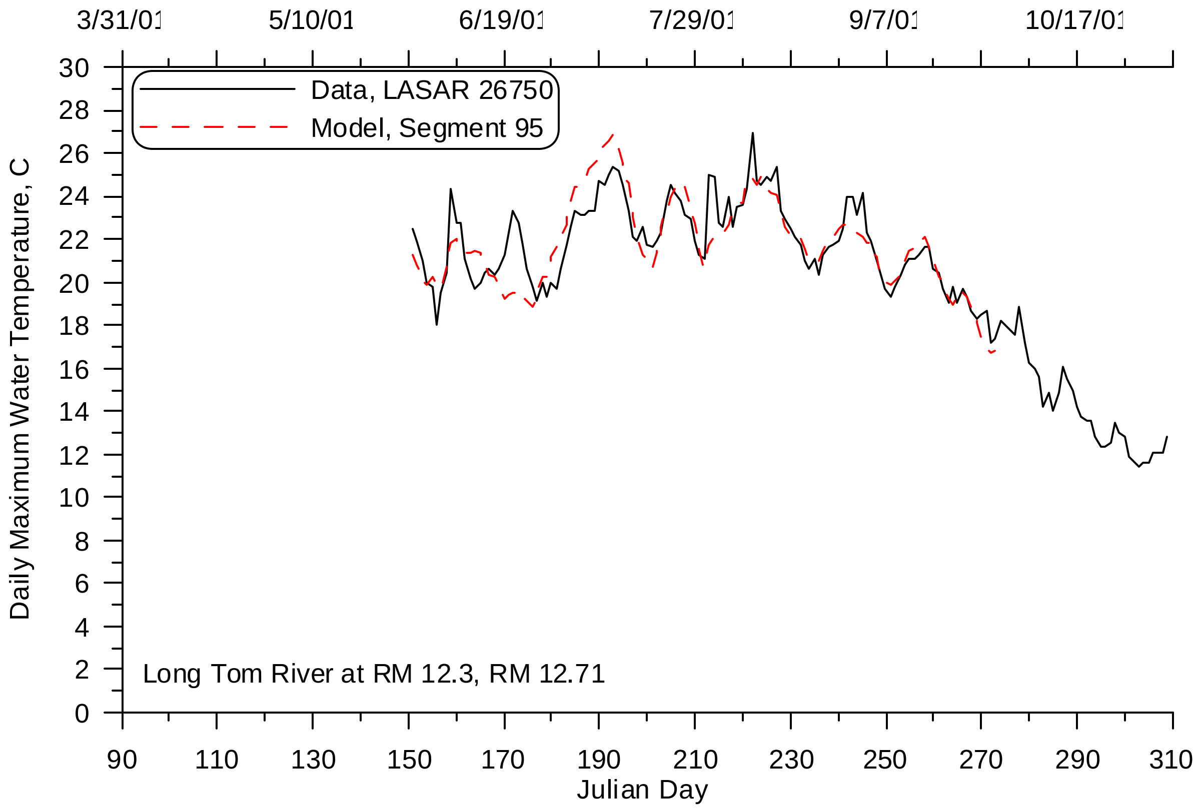

Figure 327: Long Tom River at RM 12.3 model-data daily maximum temperature comparison, 2001

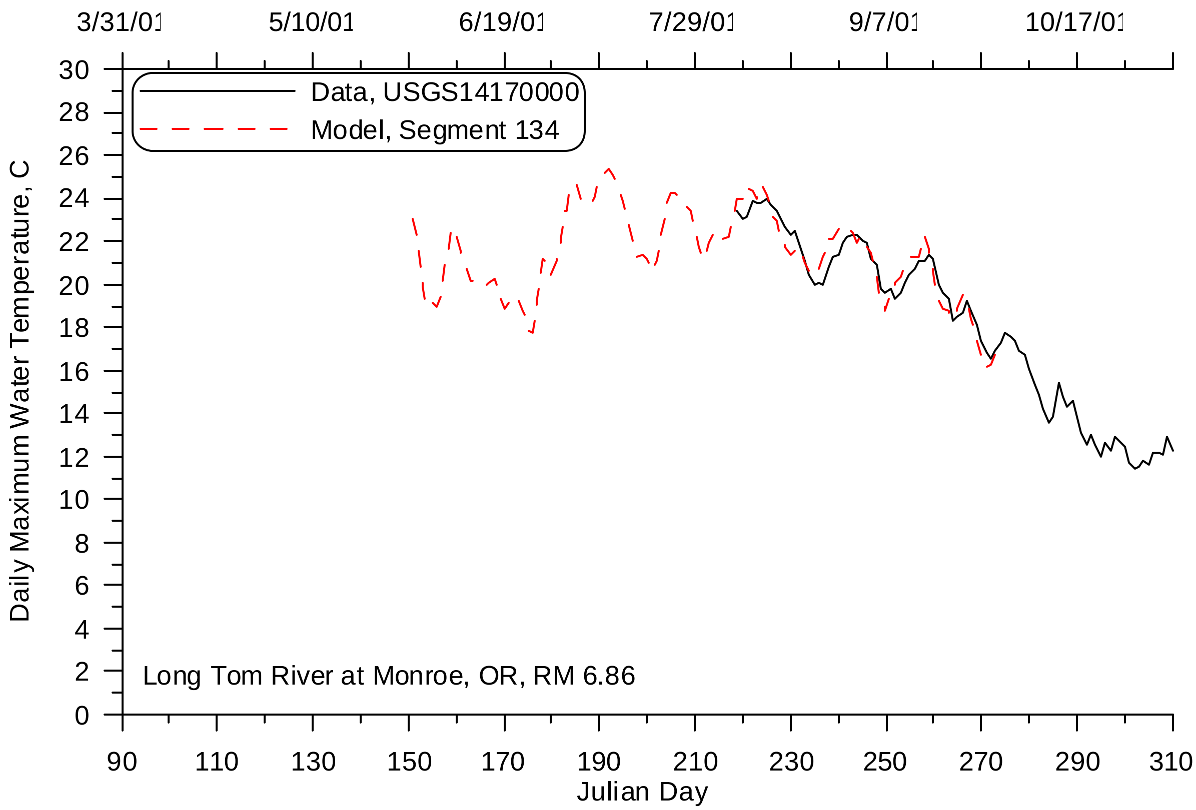

Figure 328: Long Tom River at Monroe model-data daily maximum temperature comparison, 2001

Year 2002

Table 50 lists daily maximum water temperature model-data error statistics for the 2002 Long Tom River model. Figure 329 through Figure 333 show model-data comparisons of daily maximum temperature. The model results in 2002 show better model-data agreement for daily maximum temperature than in 2001

Table 50: Long Tom River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14169000	23.47	2	183	0.04	0.06	0.09
LASAR 26749	17.75	55	125	-0.53	0.64	0.84
LASAR 26750	12.71	95	124	-0.21	0.63	0.84
USGS14170000	6.86	134	183	-0.41	0.73	0.90
LASAR 29644	0.91	176	176	-0.52	0.88	1.09

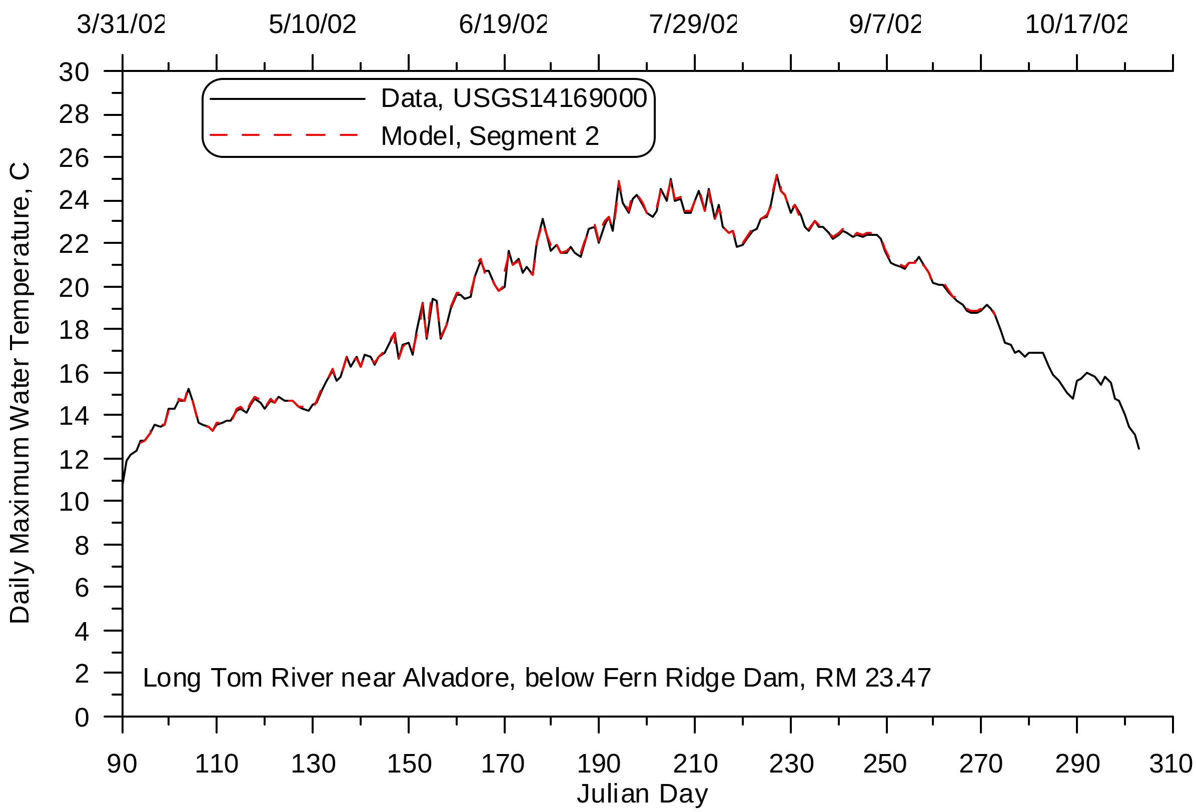

Figure 329: Long Tom River near Alvadore model-data daily maximum temperature comparison, 2002

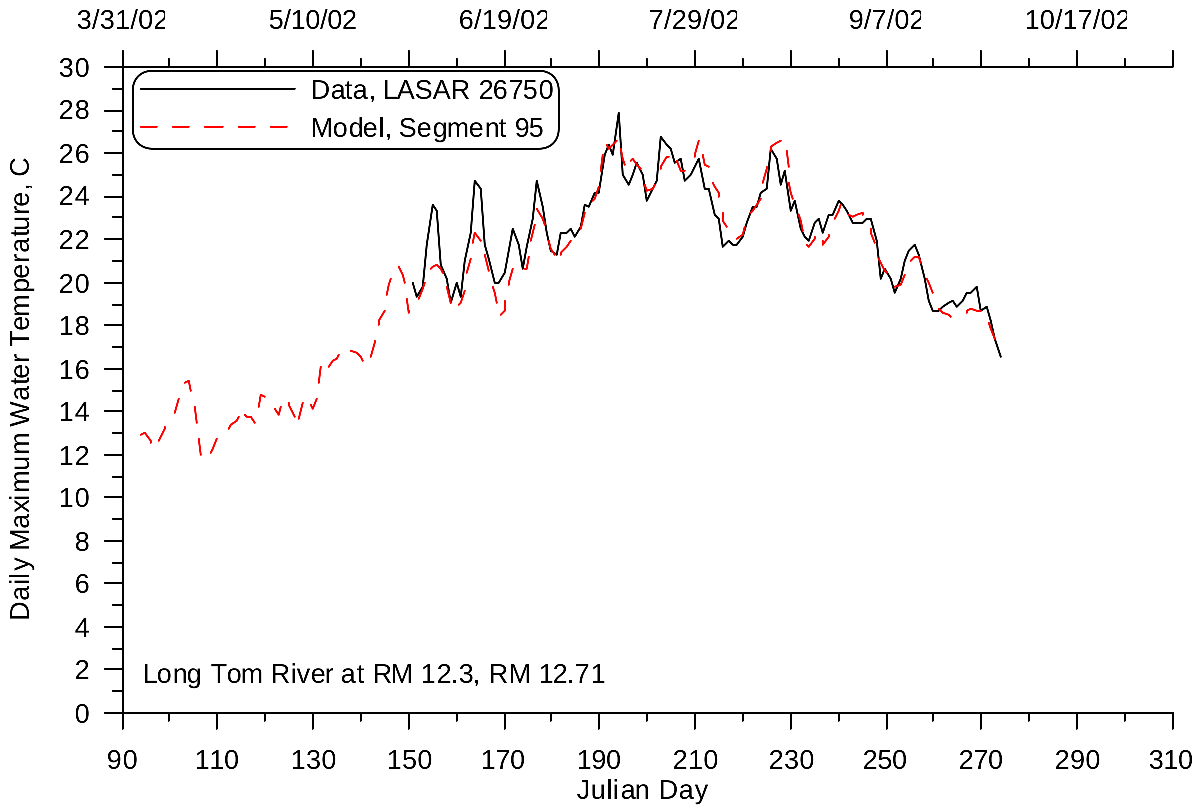

Figure 330: Long Tom River at RM 19.8 model-data daily maximum temperature comparison, 2002

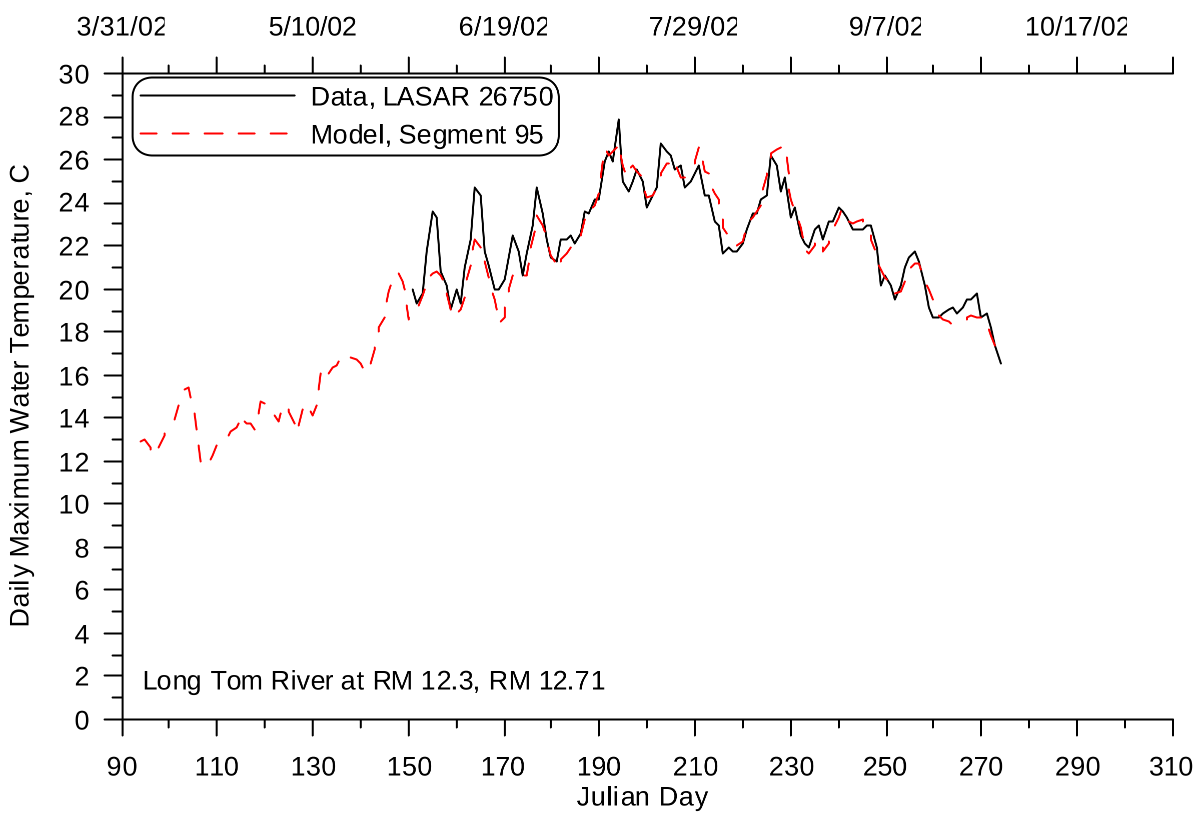

Figure 331: Long Tom River at RM 12.3 model-data daily maximum temperature comparison, 2002

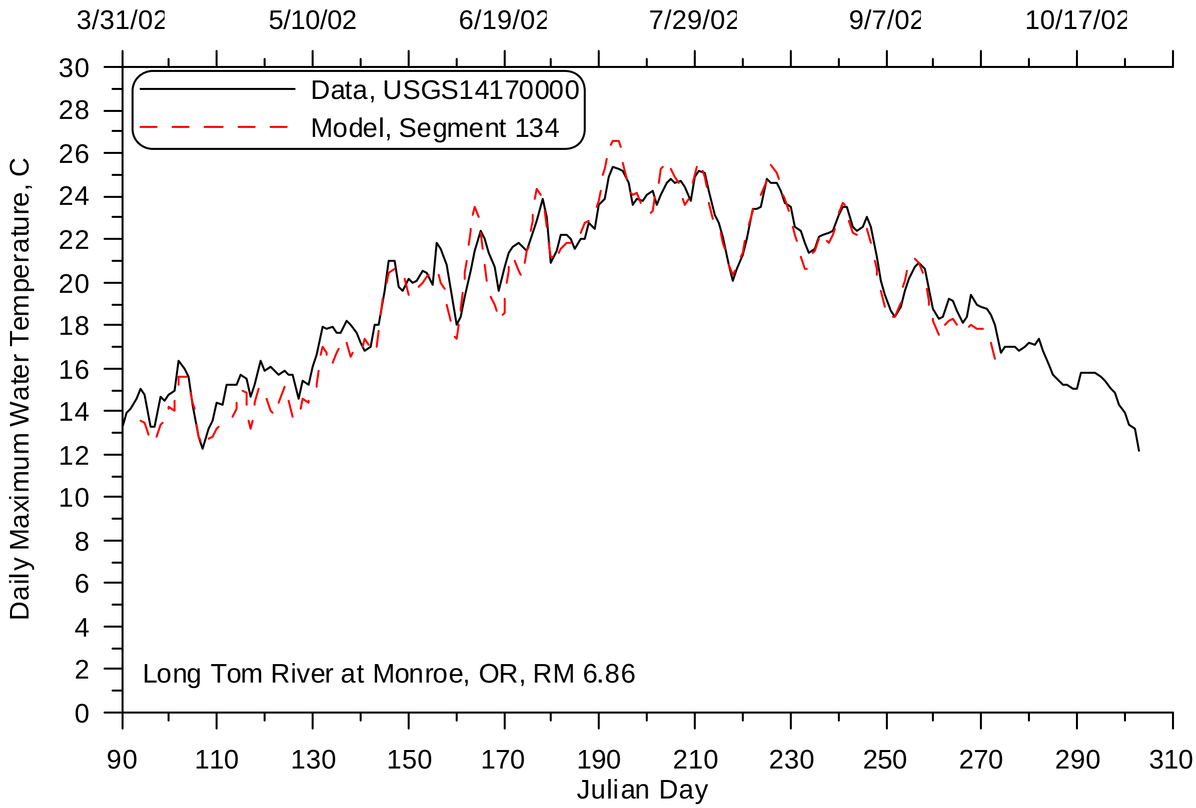

Figure 332: Long Tom River at Monroe model-data daily maximum temperature comparison, 2002

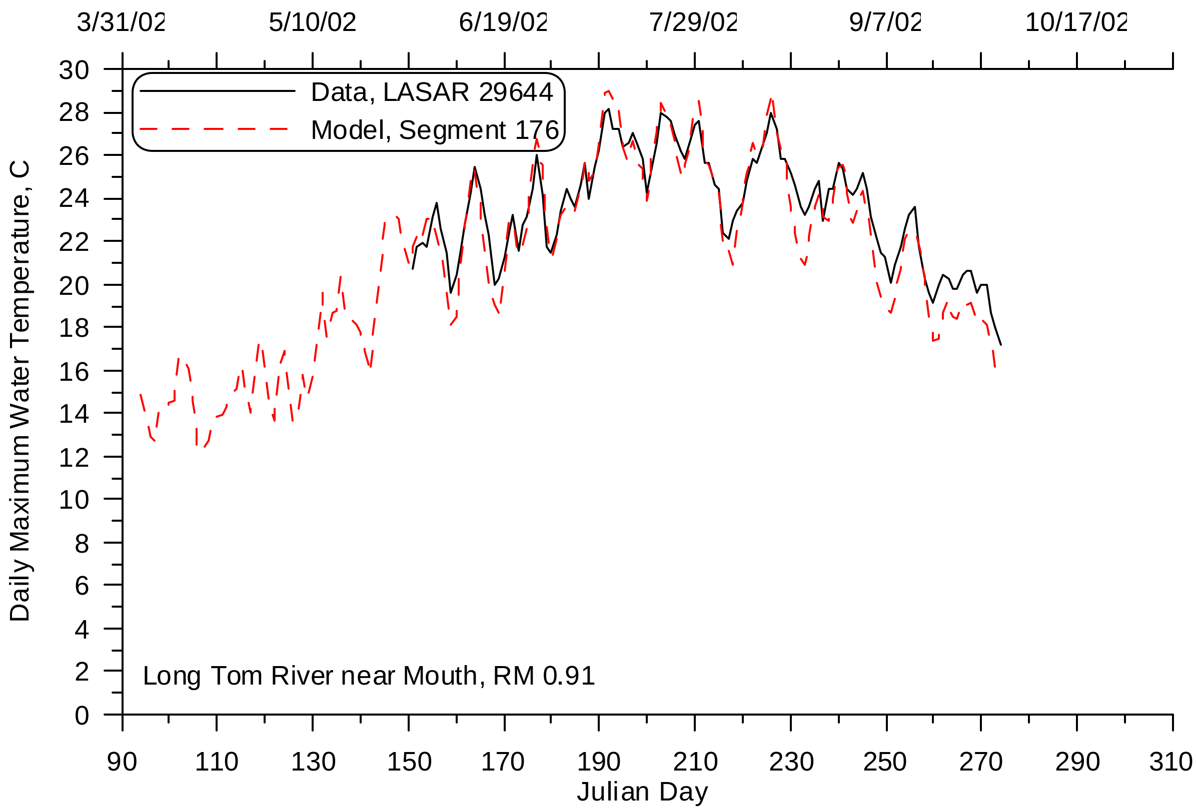

Figure 333: Long Tom River near mouth model-data daily maximum temperature comparison, 2002

McKenzie River

Introduction

The McKenzie River model calibration was performed in a series of steps. Hydrodynamics, water level and flow rates, were calibrated first, followed channel widths and then temperature. Figure 334 shows the model domain from Cougar Reservoir downstream to the river confluence with the Willamette River. The model calibration period for 2001 was from May 20 to October 15 and for 2002 from April 1 to October 31.

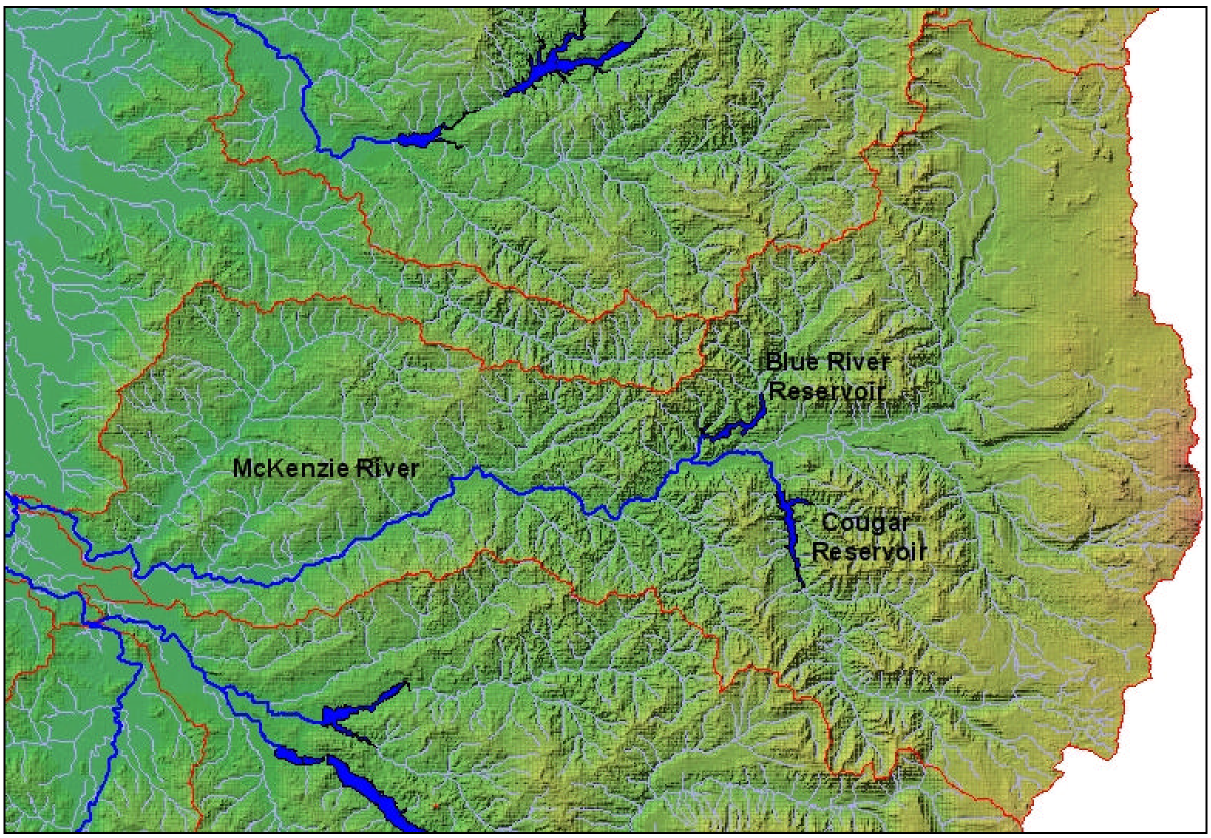

Figure 334: McKenzie River model region

Hydrodynamics

Hydrodynamics were calibrated using water level and flow data. The only calibration parameters used were Manning's friction factor, adjustments to the channel slope and the channel widths since there was limited bathymetric data for the river.

Flow and Water Surface Elevation

The McKenzie River basin has four gage stations with continuous flow and water surface elevation data for calibrating the model. Figure 335 shows a map of the basin with the gage site locations and Table 51 shows a list of the gage sites with RM and corresponding model segment.

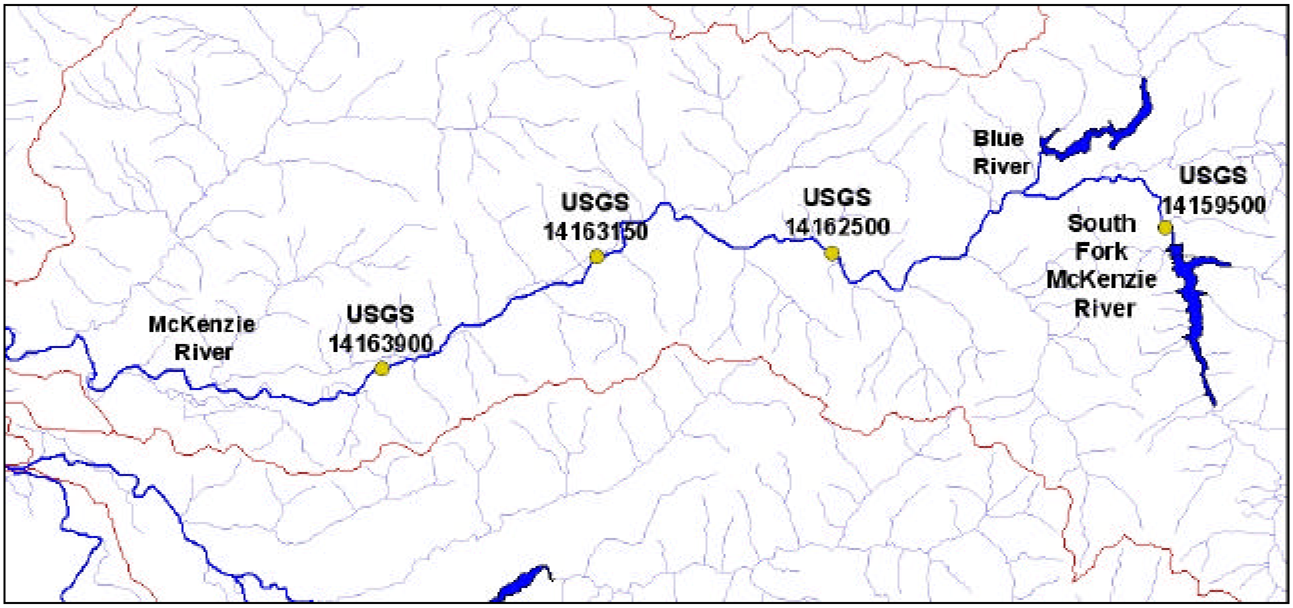

Figure 335: McKenzie River hydrodynamic calibration site locations

Table 51: McKenzie River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14159500	South Fork McKenzie below Cougar Dam	60.39	4	Q & WL
USGS 14162500	McKenzie River near Vida, OR	44.56	108	Q & WL
USGS 14163150	McKenzie River below Leaburg Dam	34.11	177	Q & WL
USGS 14163900	McKenzie River near Walterville, OR	24.97	240	Q & WL

The hydrodynamics were calibrated moving downstream and incorporating the Eugene Water and Electric Board (EWEB) operations based on standard operating rules (phone conversation: Catrin van Donkelaar, EWEB, 2003). The model output just upstream of the Leaburg and Walterville canal diversions was used with the operating rules to estimate the flow diversion. In 2002 there was no flow in the Walterville canal due to maintenance work and other projects. Water balance flows were added to the model several segments upstream of the gage station calibration points. The water balance flows were included in the model as point tributaries rather than as distributed tributaries over model water bodies since the calibration points fell within the model water bodies. An iterative process of updating the water balance flows, updating the canal diversions was conducted on Leaburg canal and then Walterville canal. Since there were no gage stations below RM 25 there was no way to ensure an appropriate water balance was developed for the lowest reach of the river before its confluence with the Willamette River.

Year 2001

The hydrodynamics calibration was conducted from May to October in 2001 for both flow and water level. Table 52 list the model-data error statistics for both flow and water level. The error statistics show good model-data agreement throughout the system for both flow and water level with the furthest downstream gage station (USGS 14163900) below the Walterville Canal diversion having the largest model-data error.

Figure 336 and Figure 337 show model results and data plotted for the South McKenzie River below Cougar Dam for both flow and water level, respectively. Since this gage station is only two segments downstream from the upstream boundary condition the results are expected to be close to the data. The vertical resolution of the model grid is 1 meter so there will be instances where the closest model-data comparisons that can be achieved will fall with one model layer. In some cases the water level stays in the same model layers for most of the simulations with deviations for the lowest and highest flows.

Figure 338 and Figure 339 show model results and data plotted for the McKenzie River near Vida, OR at RM 44.6 for flow and water level, respectively. Here the plots show good agreement between the model and data for both flow and water level.

Figure 340 and Figure 341 show model results and data plotted for the McKenzie River below the Leaburg diversion dam at RM 34.1 for flow and water level, respectively. The flow plot shows close model-data agreement over the simulation and the water level plot shows close agreement with the model having a slight bias above the data.

Figure 342 and Figure 343 show model results and data plotted for the McKenzie River near Walterville which is below the Walterville diversion dam at RM 25 for flow and water level, respectively. The model-data flow comparison shows good agreement. The water level comparison shows the model has a consistent bias with water level higher than the data. These results also fall primarily within one model layer. To improve the water level model-data agreement at this location further information is need about the channel bathymetry. The model is conveying the appropriate quantity of water at this location.

Table 52: McKenzie River hydrodynamic calibration model-data error statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14159500	60.39	4	7008	0.00	0.03	0.07
USGS 14162500	44.56	108	7008	-0.02	0.26	0.42
USGS 14163150	34.11	177	7008	-0.03	0.21	0.50
USGS 14163900	24.97	240	6996	-0.04	0.30	0.62
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14159500	60.39	4	7008	-0.01	0.03	0.04
USGS 14162500	44.56	108	7008	-0.08	0.08	0.08
USGS 14163150	34.11	177	7008	-0.02	0.02	0.03
USGS 14163900	24.97	240	6996	0.16	0.16	0.16

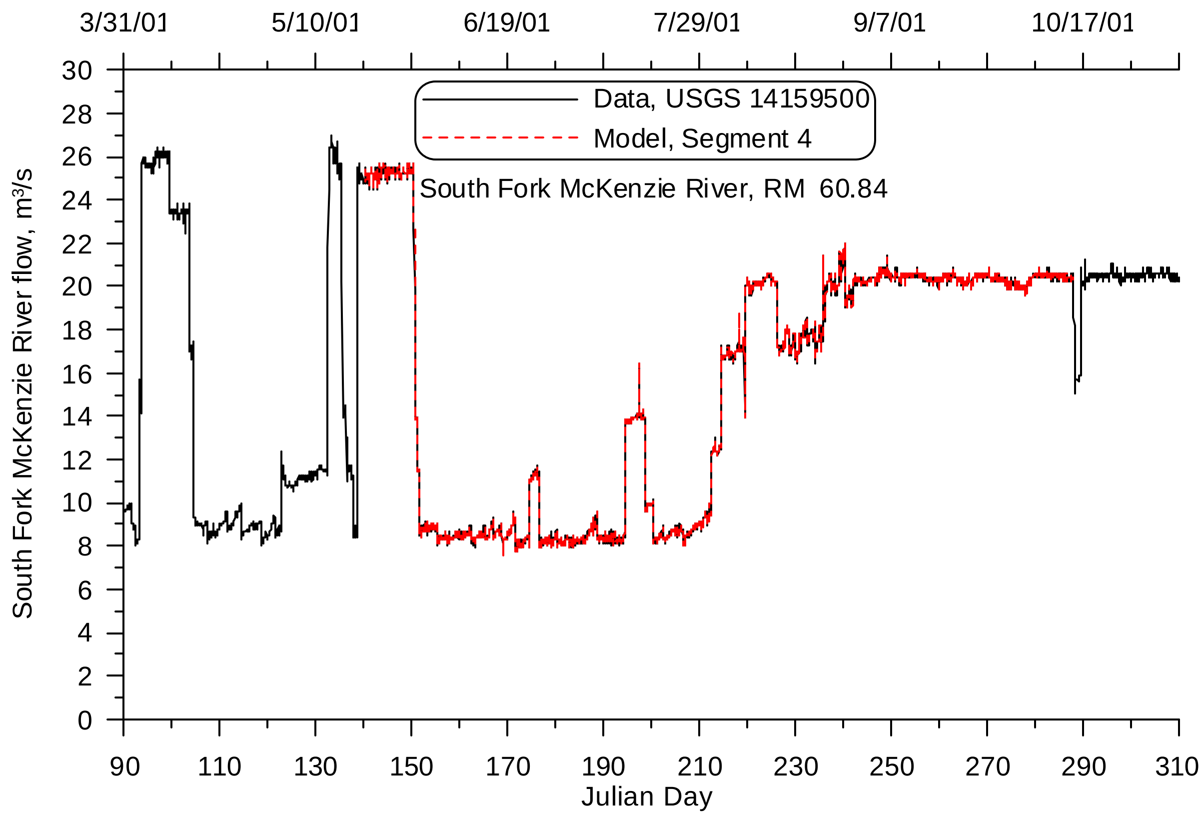

Figure 336: South Fork McKenzie River below Cougar Dam model-data flow comparison, 2001

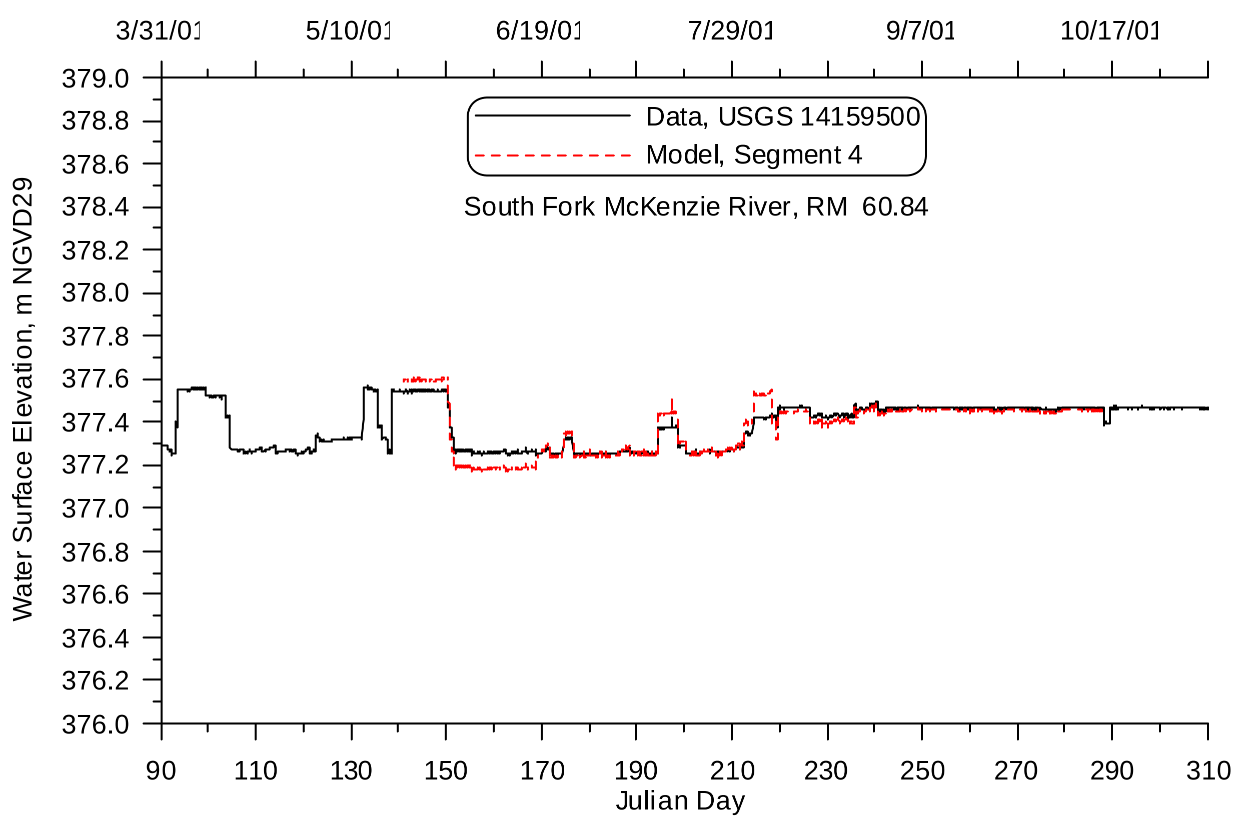

Figure 337: South Fork McKenzie River below Cougar Dam model-data water level comparison, 2001

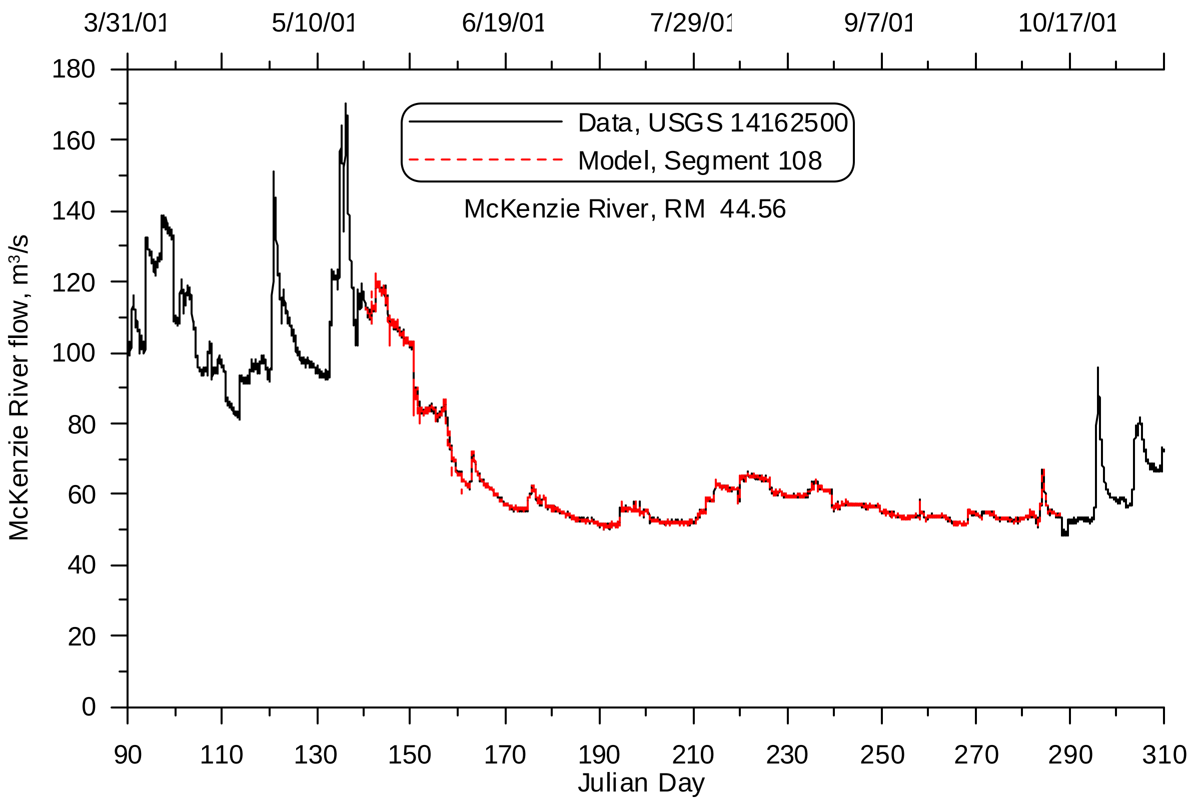

Figure 338: McKenzie River near Vida model-data flow comparison, 2001

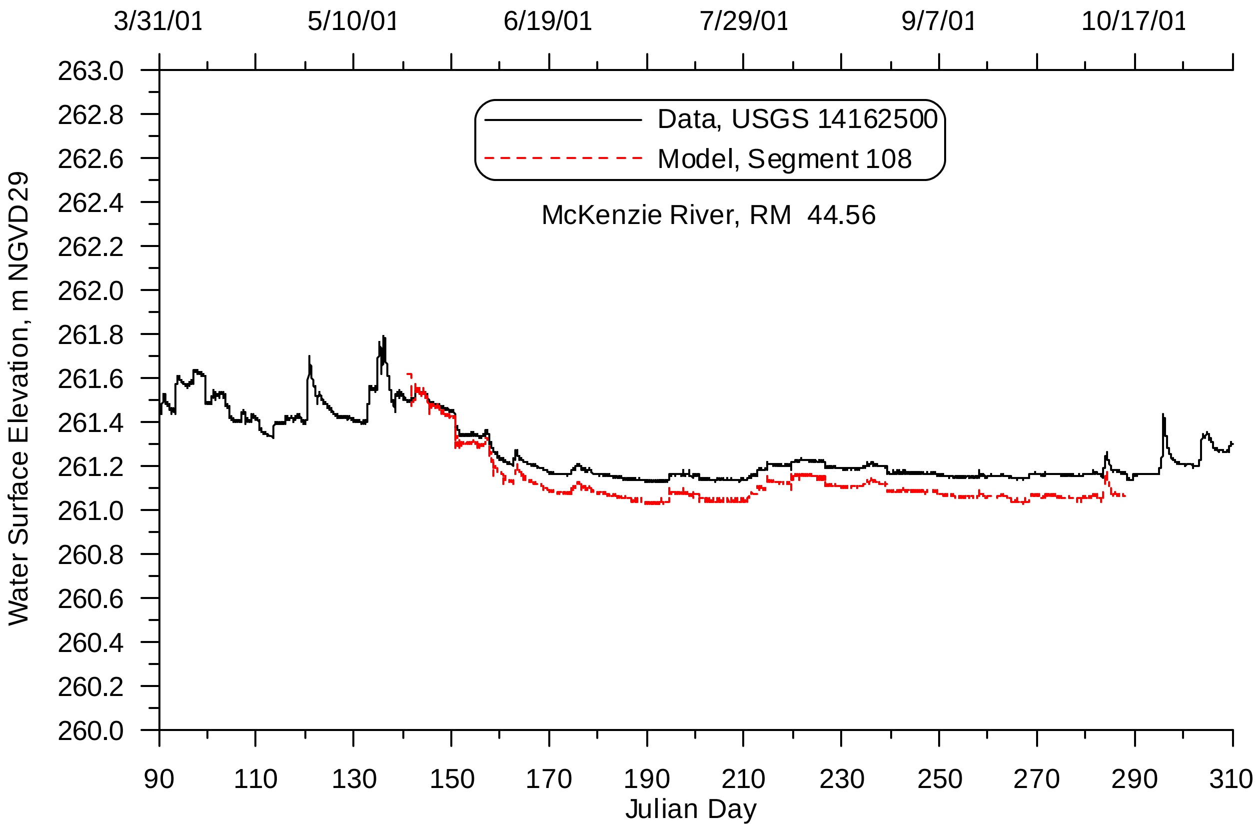

Figure 339: McKenzie River near Vida model-data water level comparison, 2001

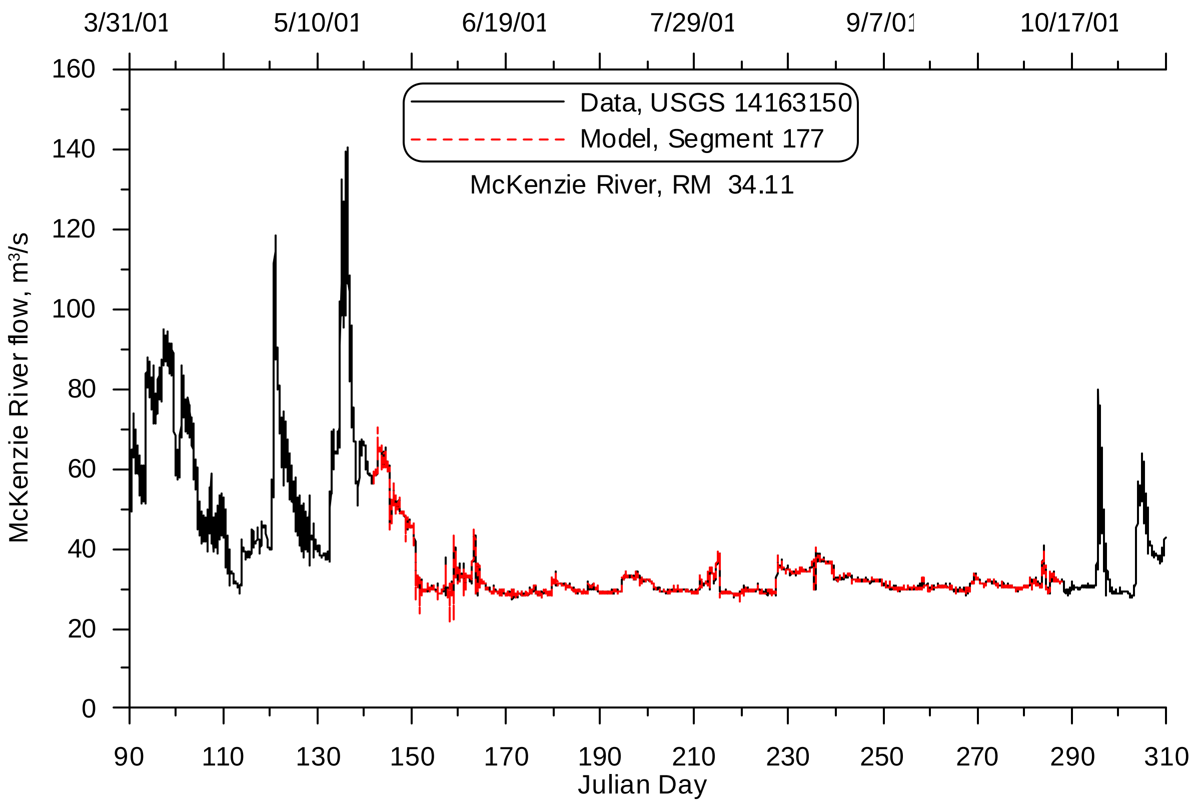

Figure 340: McKenzie River below Leaburg Dam model-data flow comparison, 2001

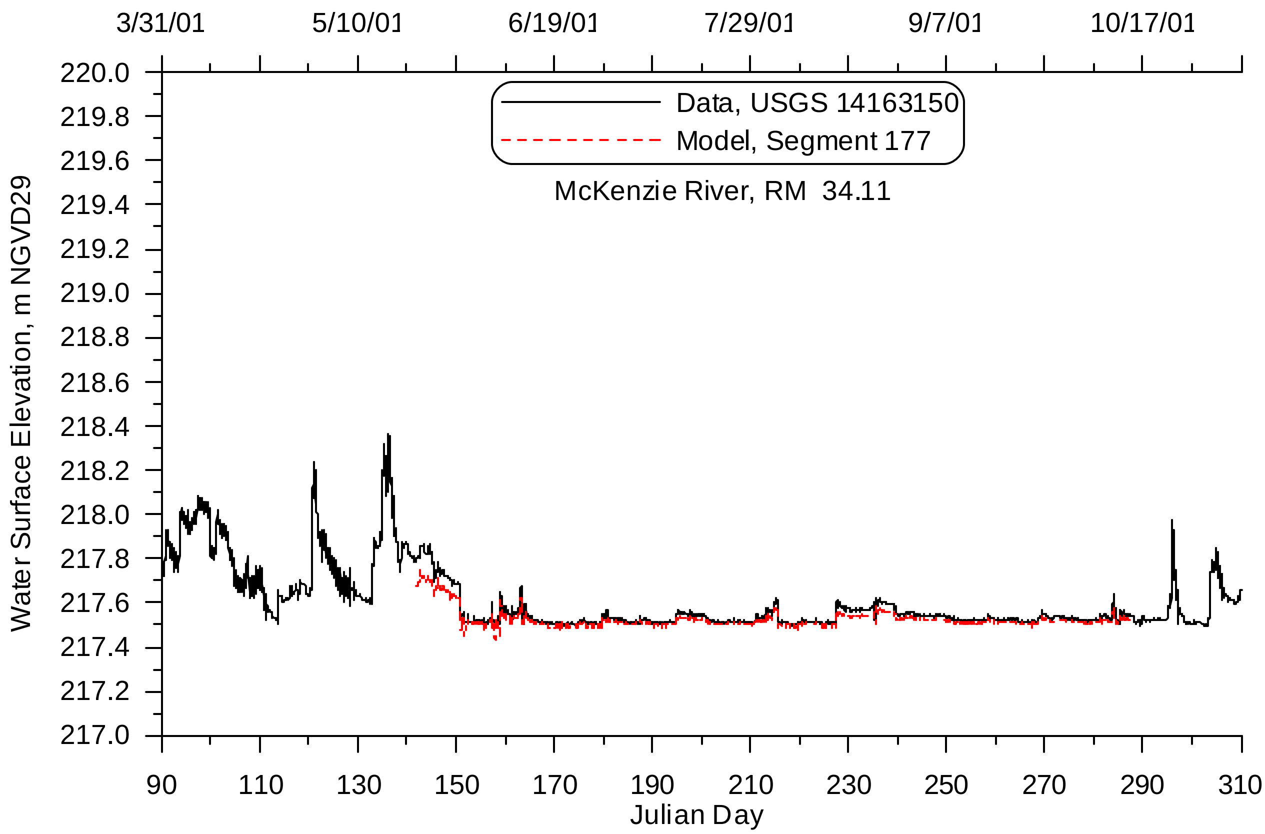

Figure 341: McKenzie River below Leaburg Dam model-data water level comparison, 2001

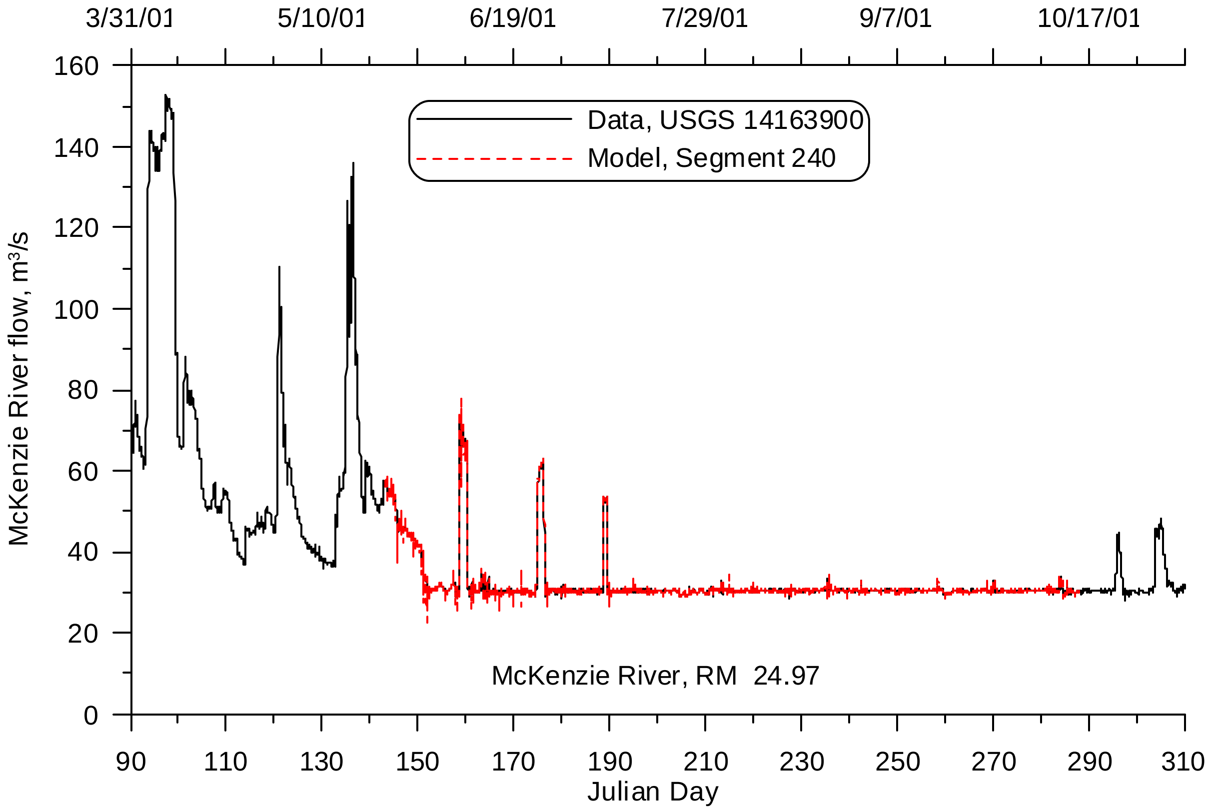

Figure 342: McKenzie River near Walterville model-data flow comparison, 2001

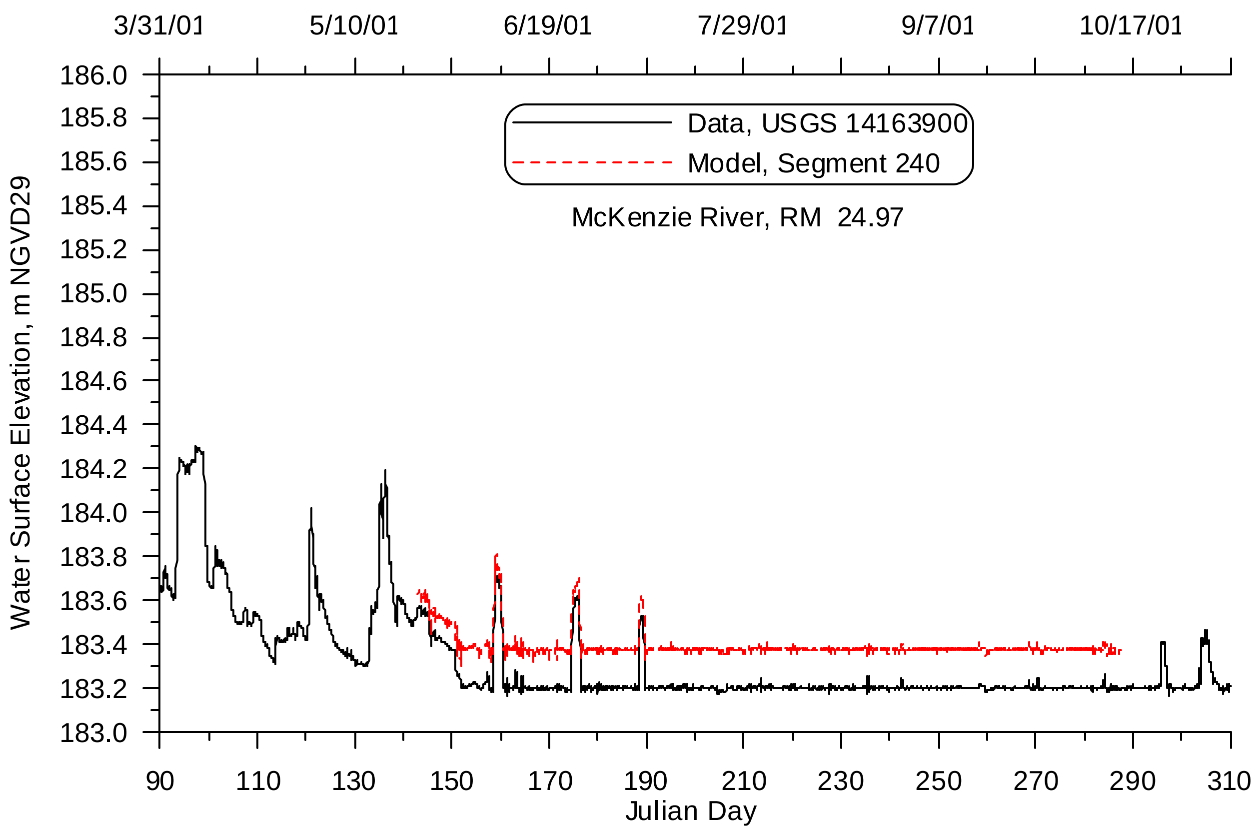

Figure 343: McKenzie River near Walterville model-data water level comparison, 2001

Year 2002

The hydrodynamics calibration was conducted form April through the end of October in 2002 for both flow and water level. Table 53 lists the model-data error statistics for both flow and water level. The error statistics show good model-data agreement throughout the system for both flow and water level with the model-data errors getting larger moving downstream. The model bathymetry and grid setup were kept the same between the 2001 and 2002 year simulations. Although the flow and water level model-data errors for 2002 were slightly than 2001 there are still small compared to the larger flows run through the model in 2002.

Figure 344 and Figure 345 show model results and data plotted for the South McKenzie River below Cougar Dam for both flow and water level, respectively. Since this gage station is only two segments downstream from the upstream boundary condition the results are expected to be close to the data. The model-data flow comparison shows good agreement. The water level shows less agreement between the model and data at this location for the highest flows. The vertical resolution of the model grid is 1 meter so there will be instances where the closest model-data comparisons that can be achieved will fall with one model layer. In some cases the water level stays in the same model layers for most of the simulations with deviations for the lowest and highest flows.

Figure 346 and Figure 347 show model results and data plotted for the McKenzie River near Vida, OR at RM 44.6 for flow and water level, respectively. Here the flow plot shows good agreement between the model and data but the water level plot indicates there are periods during higher flows when there is less agreement the model and data. These deviations still fall within the 1 meter layer thickness of the grid.

Figure 348 and Figure 349 show model results and data plotted for the McKenzie River below the Leaburg diversion dam at RM 34.1 for flow and water level, respectively. The plots show close model-data agreement over the simulation for both the flow and water level results.

Figure 350 and Figure 351 show model results and data plotted for the McKenzie River near Walterville which is below the Walterville diversion dam at RM 25 for flow and water level, respectively. The model-data flow comparison shows good agreement. The water level comparison shows the model has a consistent bias with water level higher than the data. As mentioned above additional channel bathymetry data is needed in this reach to further refine the model and improve the water level comparison with data.

Table 53: McKenzie River hydrodynamic calibration model-data error statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14159500	60.39	4	10175	0.00	0.05	0.29
USGS 14162500	44.56	108	10174	-0.03	0.52	1.21
USGS 14163150	34.11	177	10174	-0.05	0.94	2.18
USGS 14163900	24.97	240	10174	-0.06	1.17	4.02
Water Level						

Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14159500	60.39	4	10175	0.06	0.10	0.16
USGS 14162500	44.56	108	10174	0.00	0.12	0.16
USGS 14163150	34.11	177	10174	-0.09	0.09	0.13
USGS 14163900	24.97	240	10174	0.13	0.13	0.17

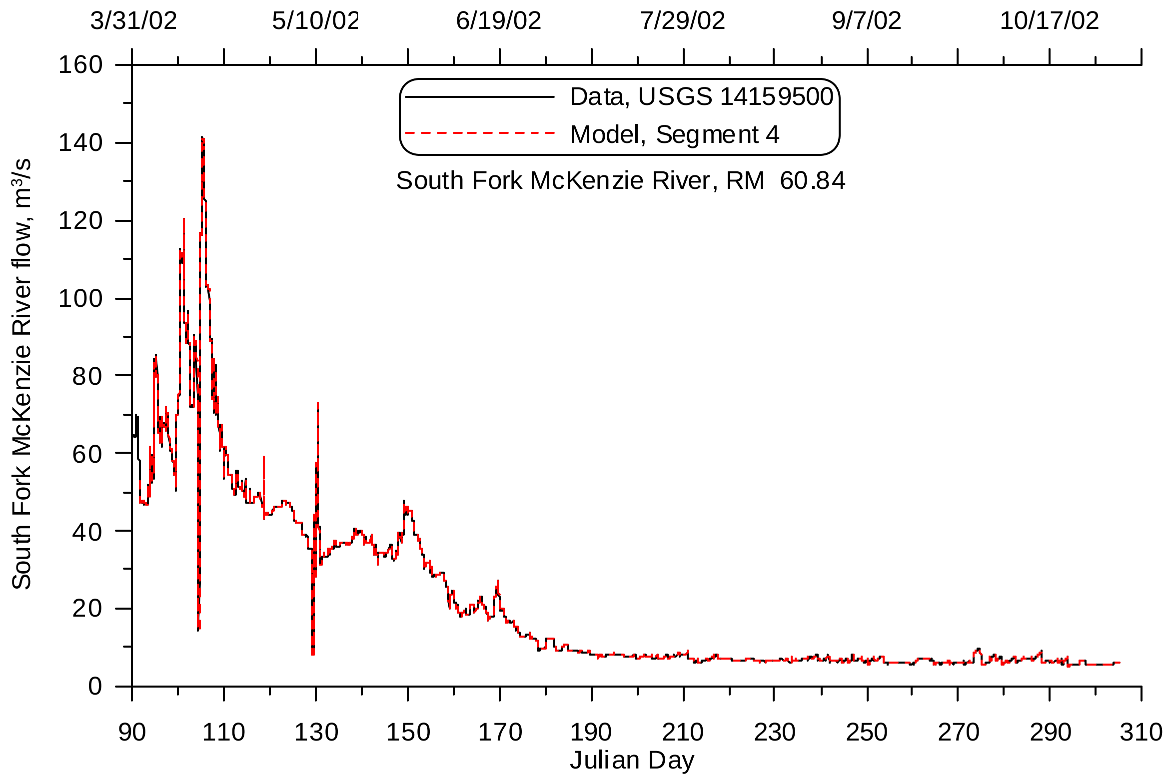

Figure 344: South Fork McKenzie River below Cougar Dam model-data flow comparison, 2002

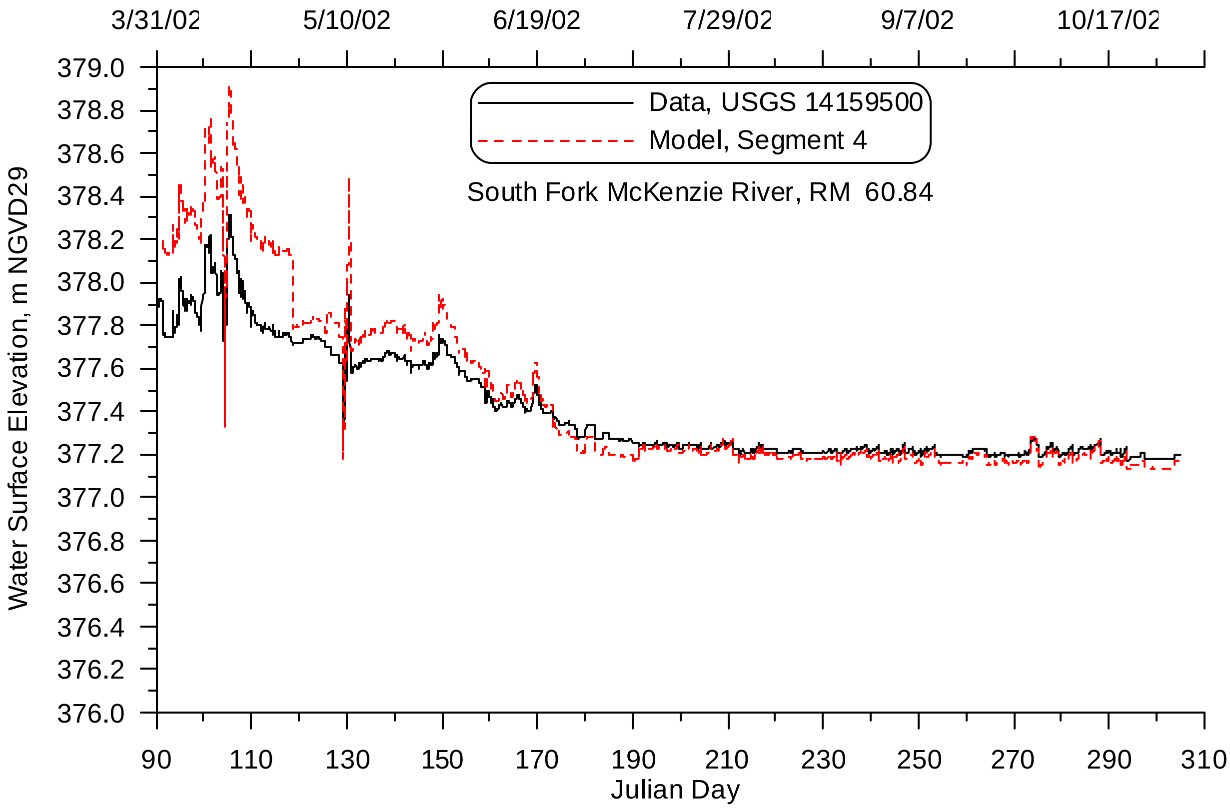

Figure 345: South Fork McKenzie River below Cougar Dam model-data water level comparison, 2002

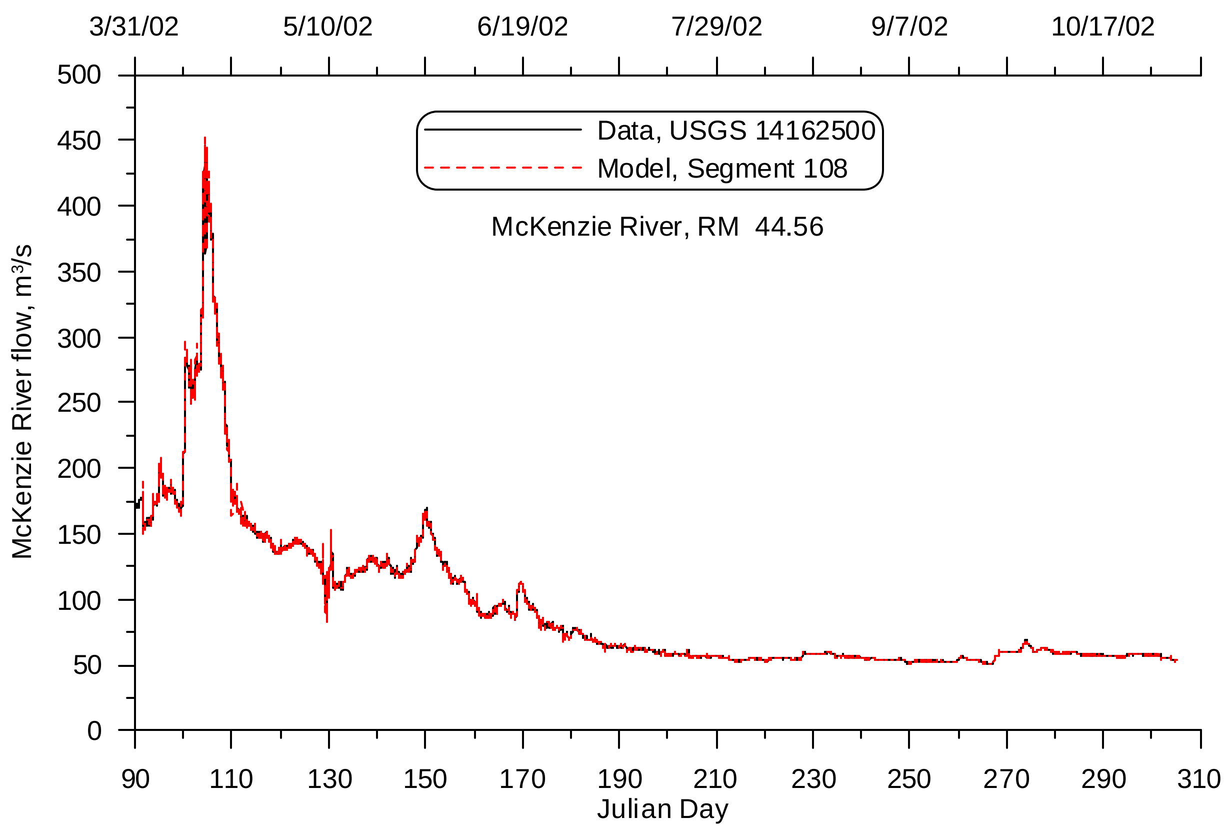

Figure 346: McKenzie River near Vida model-data flow comparison, 2002

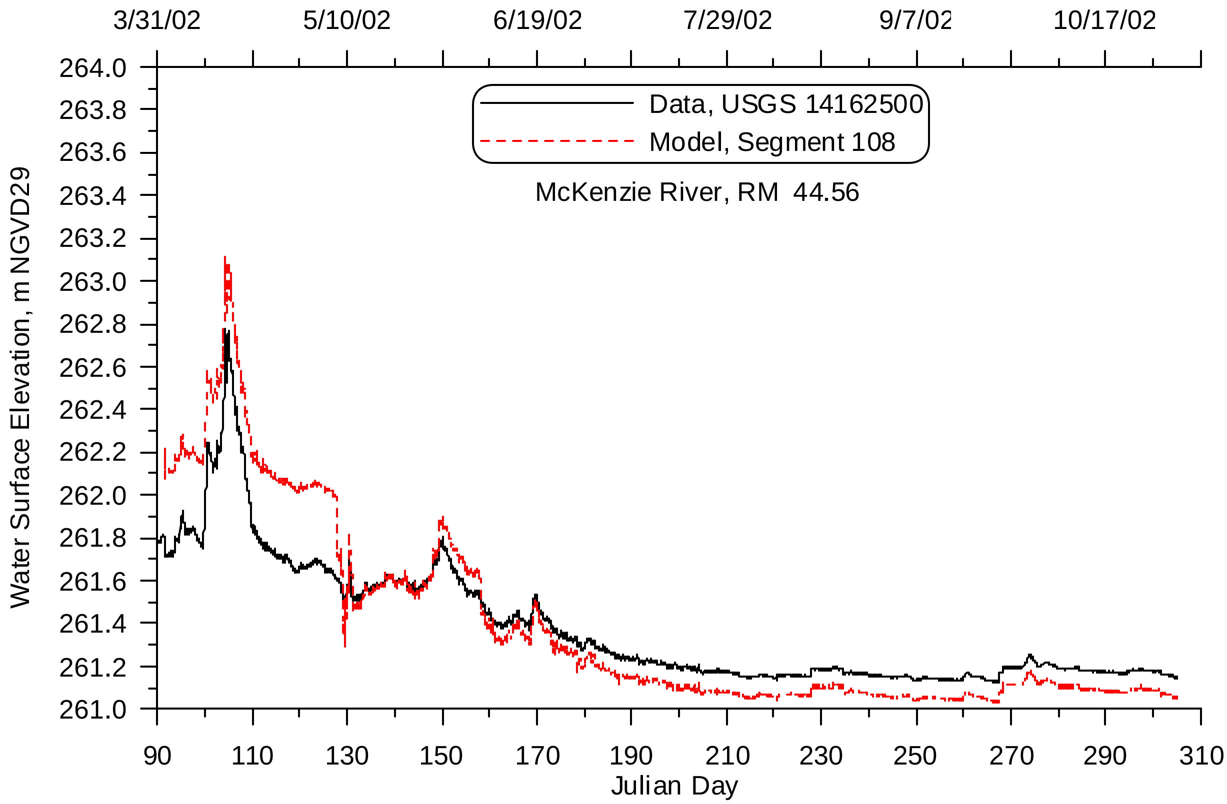

Figure 347: McKenzie River near Vida model-data water level comparison, 2002

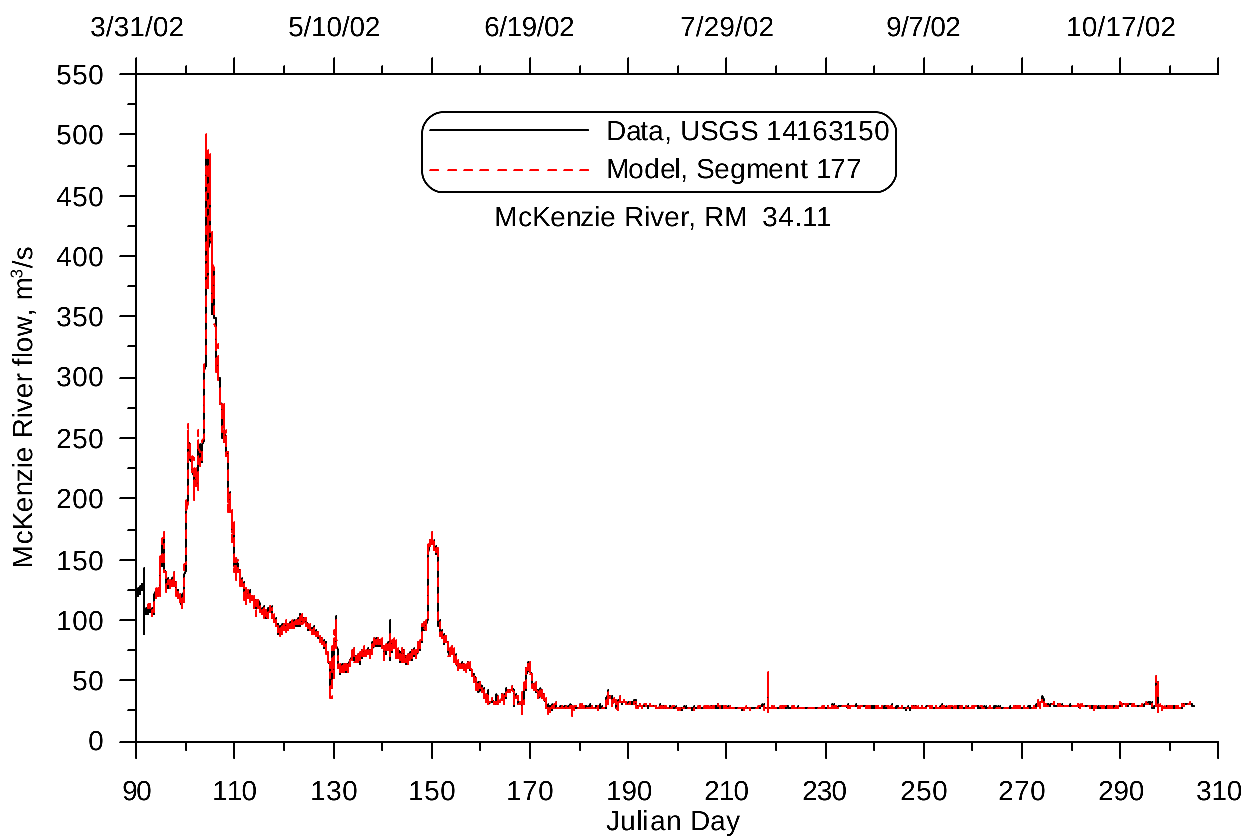

Figure 348: McKenzie River below Leaburg Dam model-data flow comparison, 2002

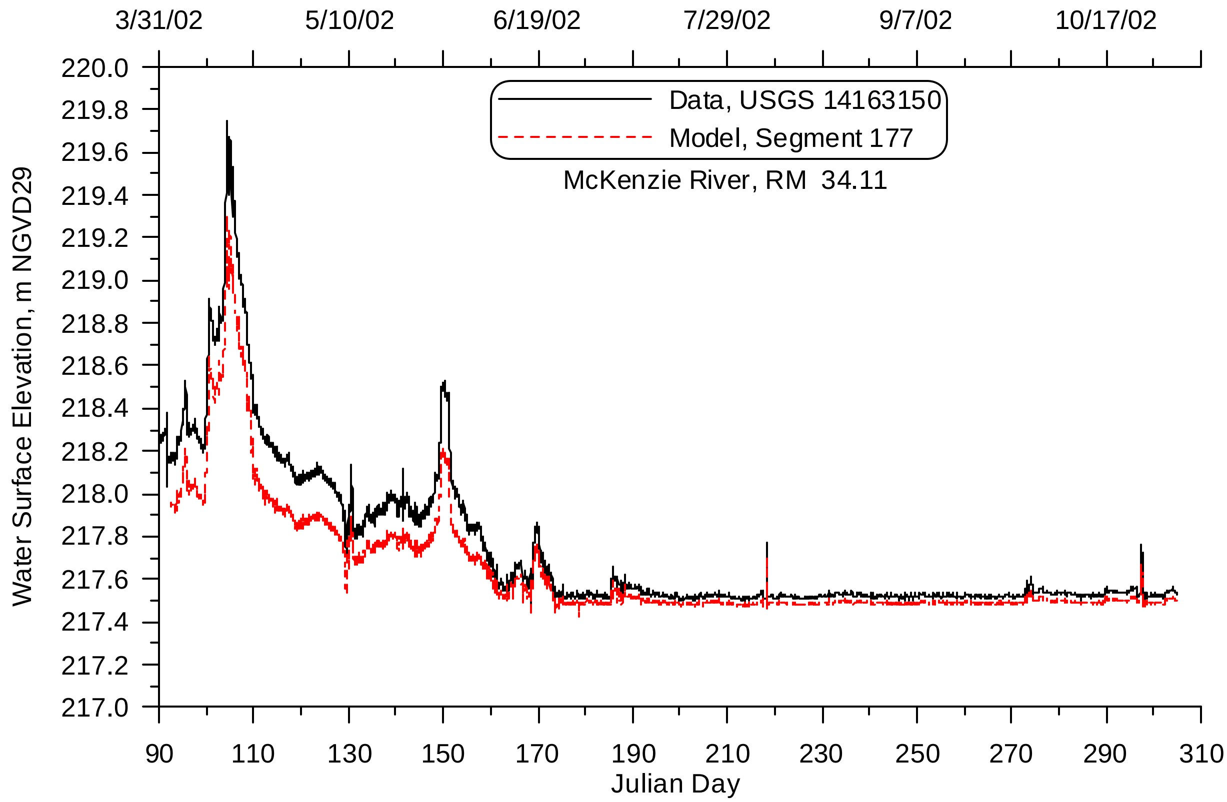

Figure 349: McKenzie River below Leaburg Dam model-data water level comparison, 2002

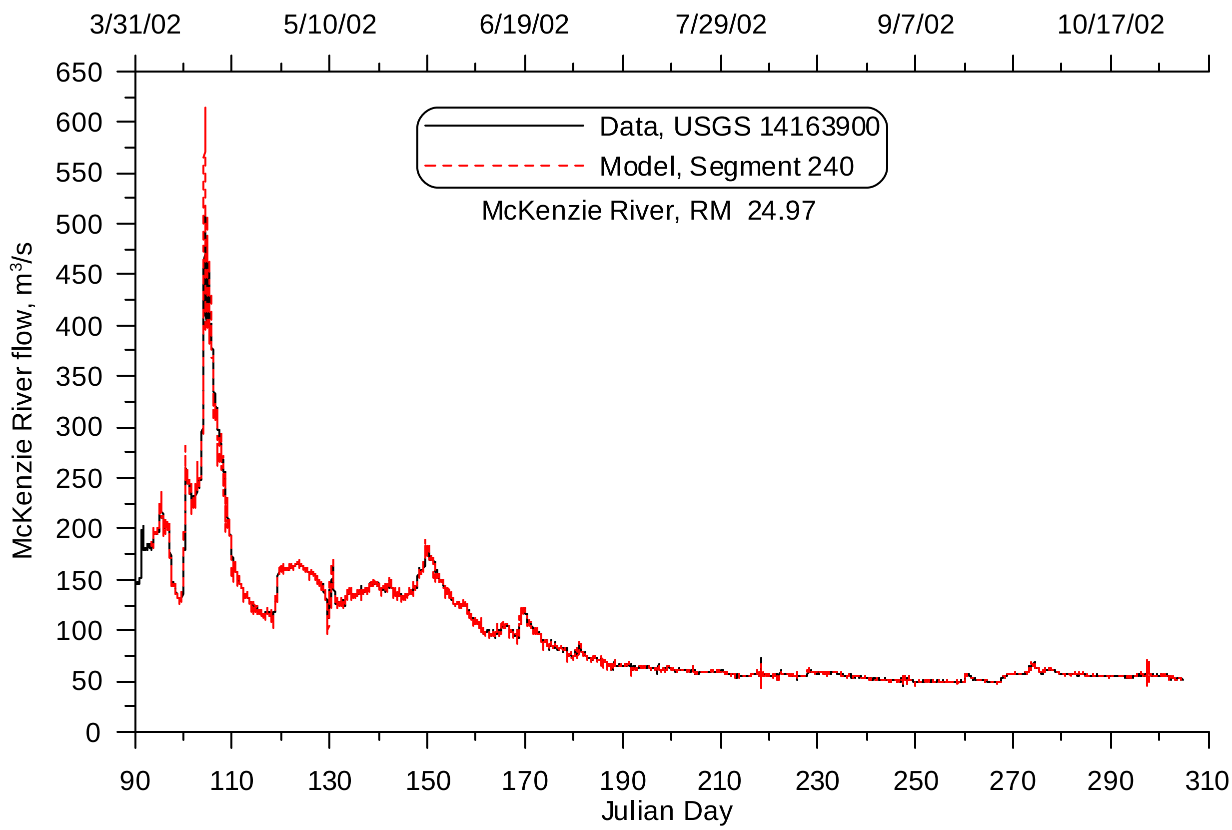

Figure 350: McKenzie River near Walterville model-data flow comparison, 2002

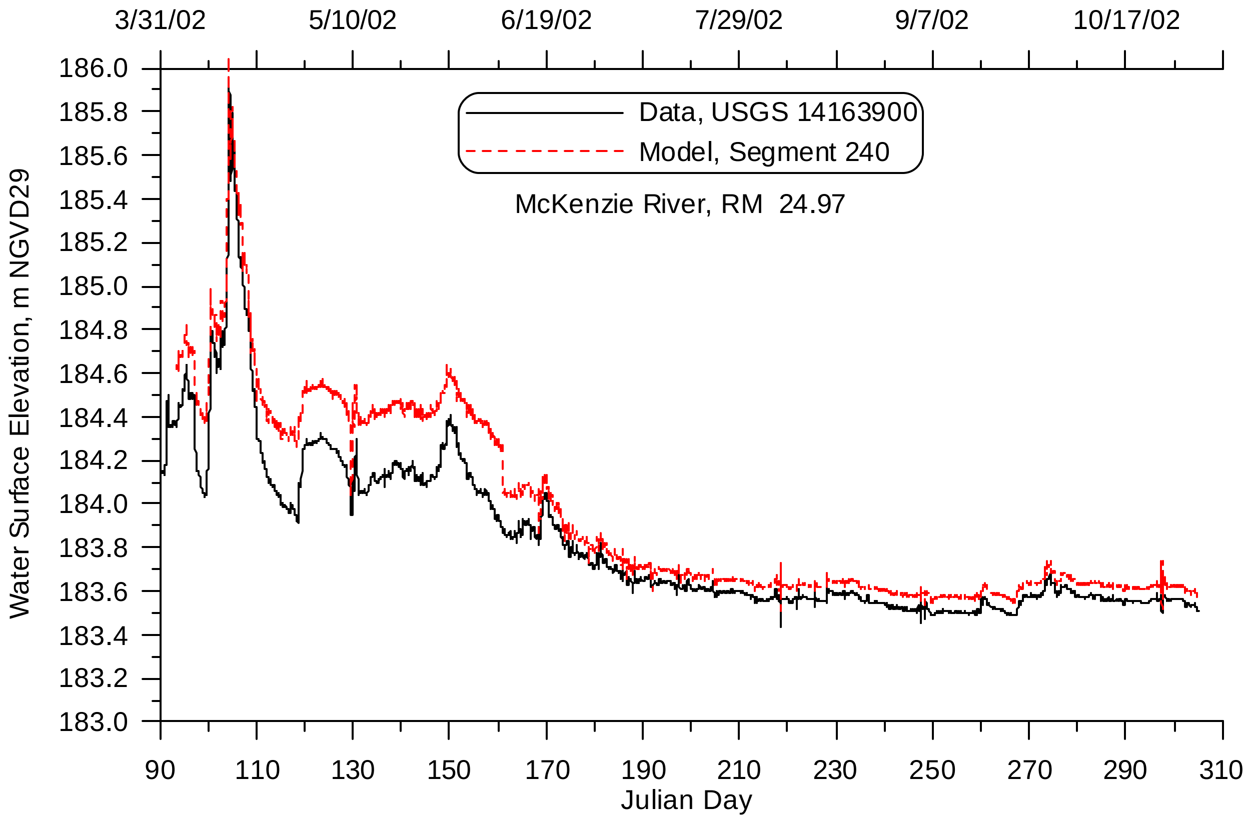

Figure 351: McKenzie River near Walterville model-data water level comparison, 2002

Channel Widths

There were two types of data utilized for comparing with simulated stream widths. The first data set is comprised of channel widths collected by the U.S. Geological Survey as part of the three field surveys conducted in the spring and summer of 2002. The second data set consists of wetted channel widths identified from digital ortho-rectified aerial photographs associated with each 7.5 minute quadrangle map in a GIS database by the Oregon Department of Environmental Quality.

USGS Width Survey

In 2002 the U.S. Geological Survey conducted three field surveys of channel widths on the McKenzie River. Since there was limited bathymetric data to develop the model grid for the river the field survey widths provide an additional model calibration data set. The surveys were conducted on April 10-12, with higher stream flows, June 3-4, with lower flows, and August 5, when the flows would be at their summer lows. Figure 352 shows the location of the survey sites. Table 54 lists the survey sites, the river mile location, and corresponding survey dates. The model was run in 2002 for calibration so channel widths were output from the model corresponding to the survey data's date, time, and location.

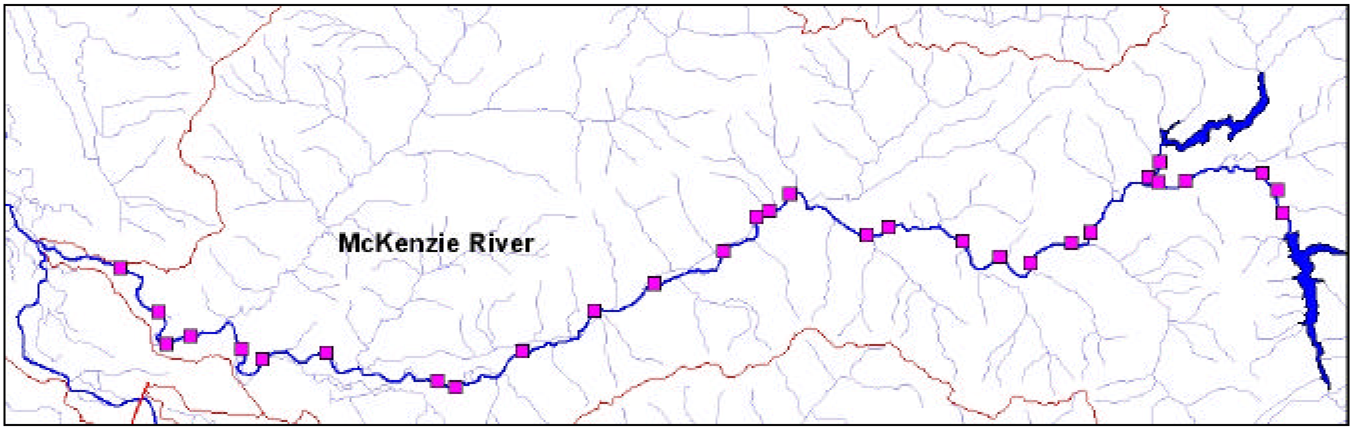

Figure 352: McKenzie River USGS width survey site locations

Table 54: McKenzie River USGS width survey sites and dates

Site Name	River Mile	Model Segment	Date 1	Date 2	Date 3
Hwy 126, nr McKenzie Valley Assembly of God	55.30	36	04/11/2002	06/03/2002	08/05/2002
Hwy 126, nr turnoff to Blue River	54.26	44	04/11/2002	06/03/2002	08/05/2002
Quartz Creek Rd bridge, Finn Rock	50.95	65	04/11/2002	06/03/2002	08/05/2002
McMullin's Landing, 50271 McKenzie Hwy	50.00	71	04/11/2002	06/03/2002	08/05/2002
Nimrod Landing	48.28	82	04/11/2002	06/03/2002	08/05/2002
Silver Creek Landing, Nimrod	46.63	93	04/11/2002	06/03/2002	08/05/2002
Rennie Boat Landing	44.62	107	04/11/2002	06/03/2002	08/05/2002
Ben/Kay Davis Park	41.67	126	04/11/2002	06/03/2002	08/05/2002
Helfrich boat ramp, Vida	40.83	132	04/10/2002	06/03/2002	08/05/2002
Good Pasture Covered Bridge	37.50	153	04/10/2002	06/03/2002	08/05/2002
Ike's Landing, upstream of Leaburg Dam	36.46	160	04/12/2002	06/03/2002	08/05/2002
Downstream from Leaburg Dam	35.72	167	04/10/2002	06/03/2002	08/05/2002
Greenwood Landing	33.69	179	04/10/2002	06/03/2002	08/05/2002
Leaburg Landing, Leaburg	30.78	200	04/10/2002	06/03/2002	08/05/2002
Dots Landing, Hwy 126	28.31	216	04/10/2002	06/03/2002	08/05/2002
Partridge Lane, Walterville	24.87	240	04/10/2002	06/03/2002	08/05/2002
Deerhorn Road	21.55	261	04/10/2002	06/03/2002	08/05/2002
Hendricks Bridge Wayside	20.91	266	04/10/2002	06/03/2002	08/05/2002
Bellinger boat ramp	15.53	300	04/10/2002	06/03/2002	08/05/2002
Camp Creek road	12.92	317	04/10/2002	06/03/2002	08/05/2002
Hayden bridge boat ramp	10.80	330	04/10/2002	06/03/2002	08/05/2002
Harvest Landing	8.22	347	04/10/2002	06/03/2002	08/05/2002
Old Orchard Lane, Springfield	7.27	353	04/10/2002	06/03/2002	08/05/2002
McKenzie View bridge	5.68	363	04/10/2002	06/03/2002	08/05/2002
Armitage Park	3.18	379	04/10/2002	06/03/2002	08/05/2002
Cougar campground gaging station	60.35	5	04/12/2002	06/04/2002	08/05/2002

Site Name	River Mile	Model Segment	Date 1	Date 2	Date 3
US Forest Service road 410 pull out	59.48	10	04/12/2002	06/04/2002	08/05/2002
US Forest Service hwy 19	58.59	16	04/12/2002	06/04/2002	08/05/2002

Figure 353 shows a plot of the USGS widths survey in April, 2002 and the wetted widths from the model at the same time as the survey. The figure show some agreement with data with a large amount of variability. The model channel widths shown in the figure had to be balanced with time of travel studies, flow data, water level data and temperature data. Figure 354 shows a plot comparing the USGS surveyed widths in June, 2002 with the wetted widths from the model at the same time. This figure indicates there is closer agreement during the lower flow period in June than in April. Figure 355 shows a plot comparing the USGS surveyed widths in August, 2002 with the wetted widths from the model at the same time. The figure indicates there is close agreement between most of the surveyed channel widths and the model predicted widths with a few exceptions.

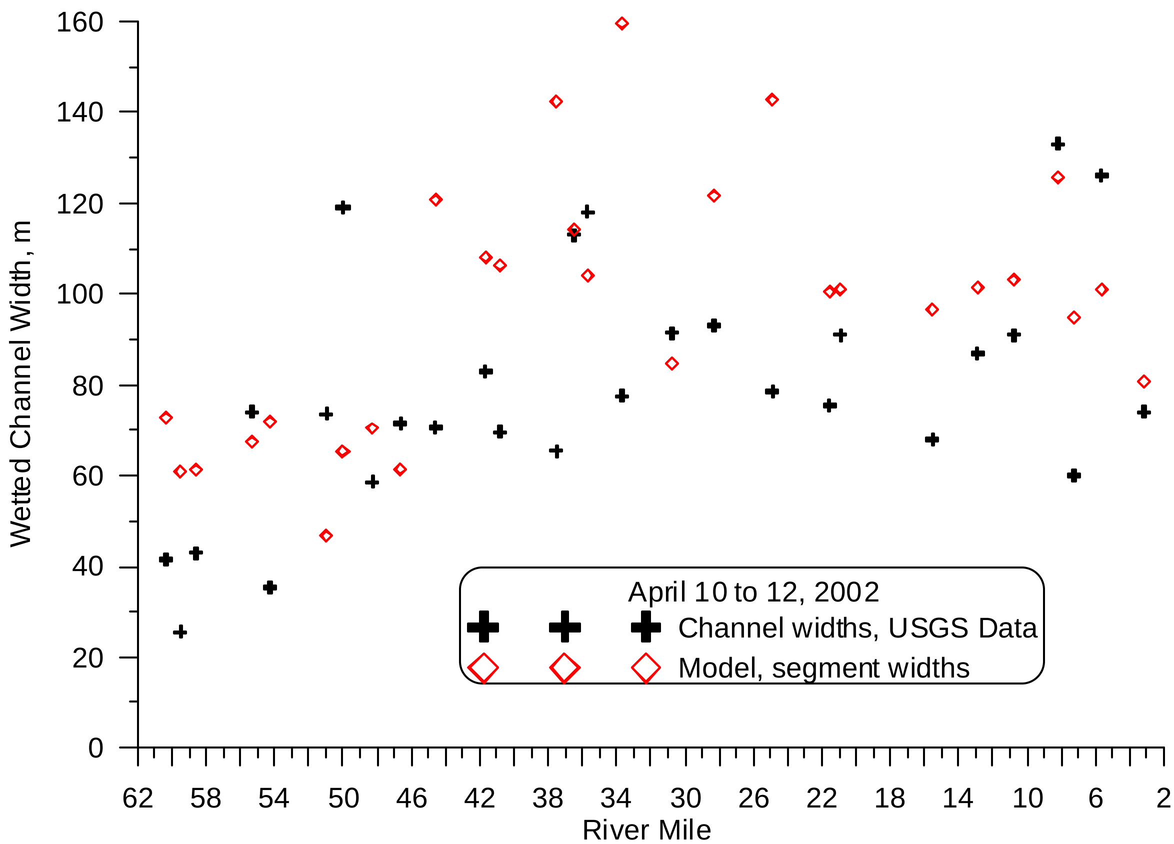

Figure 353: McKenzie River USGS and model wetted width comparison on April 10-12, 2002

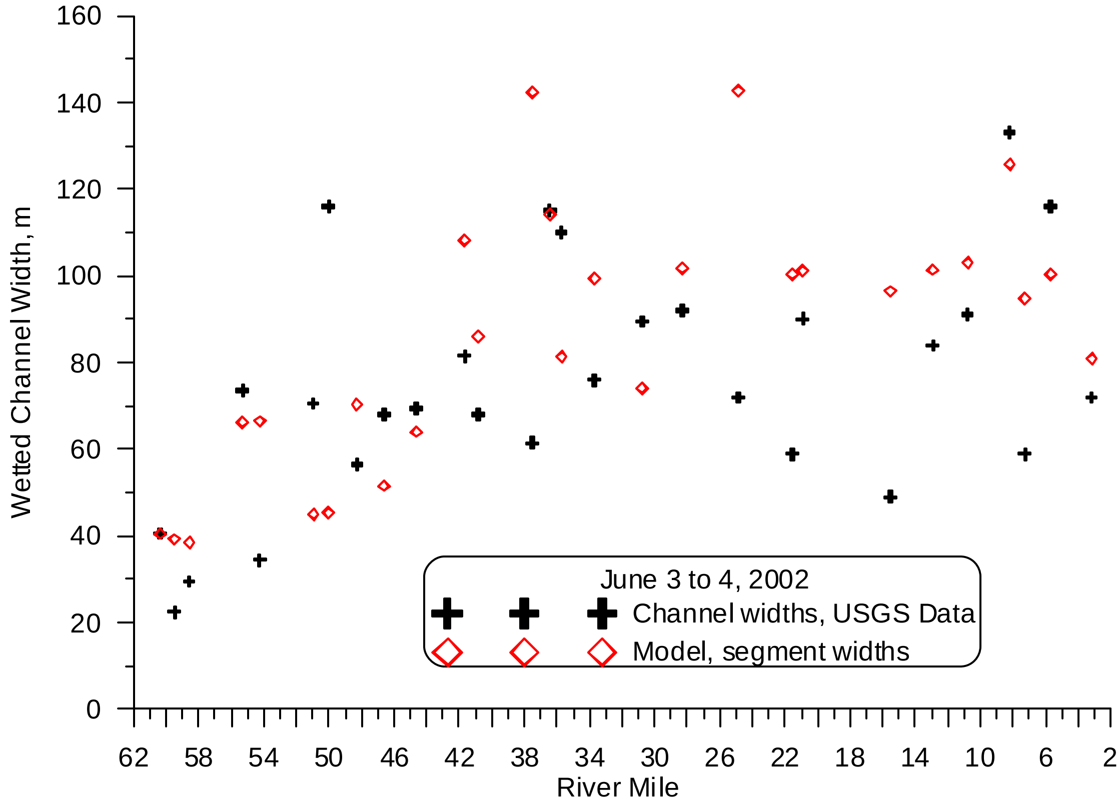

Figure 354: McKenzie River USGS and model wetted width comparison on June 3-4, 2002

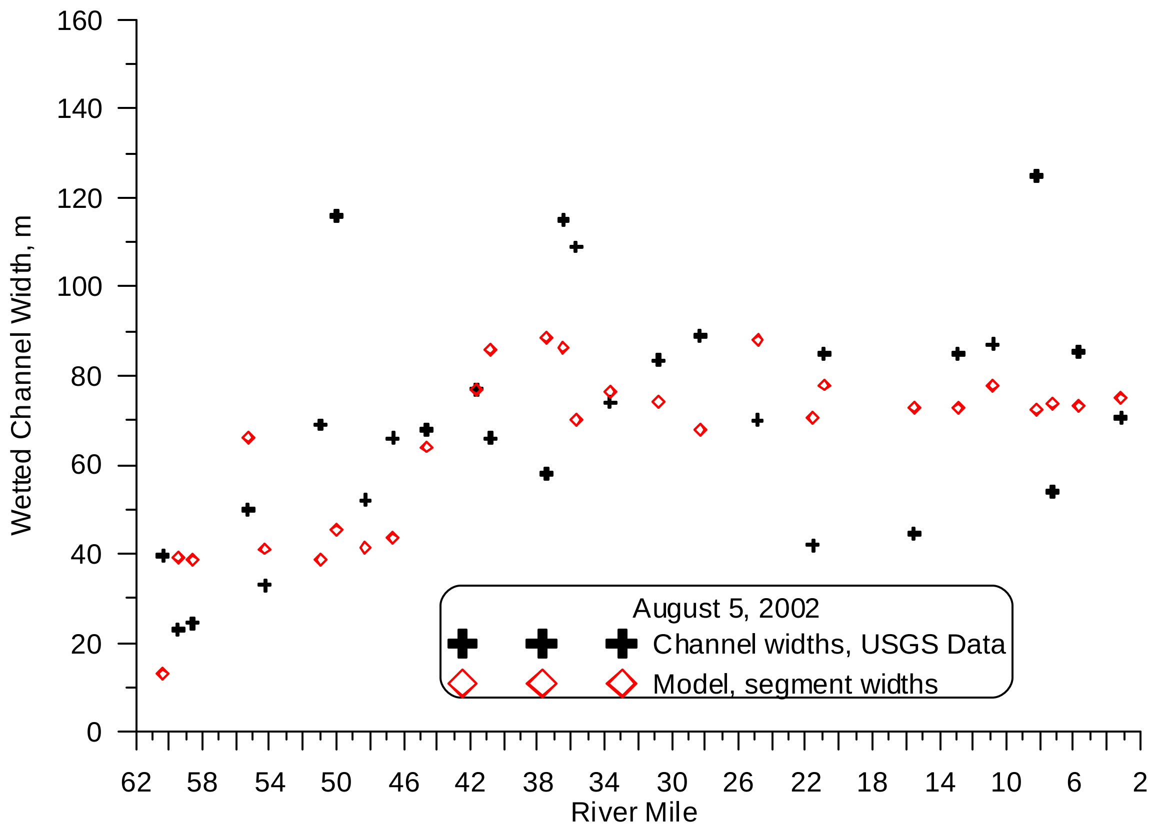

Figure 355: McKenzie River USGS and model wetted width comparison on April 10-12, 2002

DEQ GIS derived Data

Oregon Department of Environmental Quality used digital ortho-rectified aerial photographs in a GIS database to digitize the channel widths. The dates when the photos were taken was then put in a database and provided with the digitized widths. The dates of the aerial photos and their spatial range were used to identify the reaches along the river which were associated with each photo and corresponding date. The dates associated with aerial photos occurred in 1994 and 1995. Then the daily averaged flow from the nearest USGS gage station was identified for each aerial photograph date. The model was run at each flow level for a specific period of time to allow steady state conditions to develop and then the channel widths of the model segments in each reach and photos was output and compared with the digitized data. The resolution of the digitized data corresponds to every 30.5 meters along the river channel and the model output is at a resolution of every 250 m.

Figure 356 shows a comparison plot between river channel wetted widths digitized in GIS by ODEQ and model results for the same flows in the river. The figure indicates there is much less variability in the model predicted channel widths than the shown in the data. The data is at a resolution of every 30.5 m and the model grid resolution is at 250 m, which smoothes out channel width changes. As noted above with the USGS width survey data analysis, the modeled channel widths were balanced with other data sources.

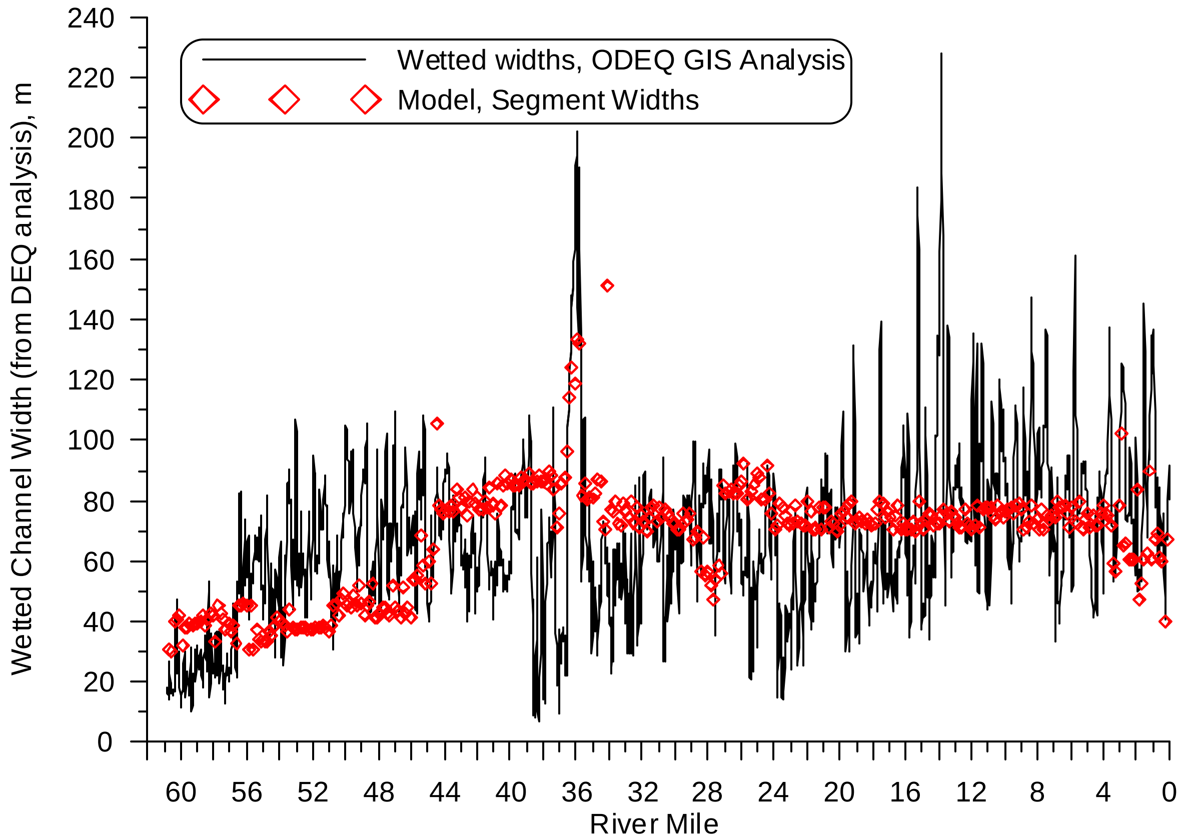

Figure 356: McKenzie River wetted width comparison between model and GIS data set

Time of Travel/Dye Studies

During the 1960's the U.S. Geological Survey conducted extensive travel rate vs. discharge studies (Harris, 1968; Appendix B, Annear et al, 2004a). The Harris Study examined time of travel for varied flows over the model of the McKenzie River model domain.

Table 55 shows the reaches examined in the study and the model segments associated with the ends of the reaches. The river mile listed in the table corresponds to the river miles generated elsewhere in this report and differ slightly from the river mile reported in the Harris Study. It is uncertain how much the channel bathymetry and travel rates may have changed between the time of travel studies in 1962-63, and the model calibration period, roughly 30 years later.

Figure 357 shows travel rate vs. flow plots for Reaches 1 to 4 (RM 56.4 to 35.7) on the McKenzie River. The figure indicates the model is doing well in simulating the travel rate through Reach 1 to 4 with the model perhaps a little too slow at higher discharge rates. Figure 358 shows travel rate vs. flow plots for Reaches 5 to 8 (RM 35.7 to 17.4) on the McKenzie River. The plots for Reaches 5 through 8 indicate there is good model-agreement with travel rates a little too fast in Reach 5. Figure 359 shows travel rate vs. flow plots for Reaches 9 to 12 (RM 17.4 to 0.0) on the McKenzie River. This last figure shows there is good model-agreement for travel rates below RM 17.4 which is a good check since there is a lack of data on inflows and outflow below RM 24.

Table 55: McKenzie River 1968 time of travel reaches, (Harris, 1968)

Reach	Upstream End	Up-stream RM	Model Segment	Downstream End	Down-stream RM	Model Segment
1	South Fork McKenzie River	56.40	30	Blue River	53.73	47
2	Blue River	53.73	47	Finn Rock bridge	50.95	65
3	Finn Rock bridge	50.95	65	Goodpasture bridge	37.48	153
4	Goodpasture bridge	37.48	153	Leaburg Dam	35.73	164
5	Leaburg Dam	35.73	164	Deerhorn Park bridge	28.67	214
6	Deerhorn Park bridge	28.67	214	Walterville Canal intake	25.61	233
7	Walterville Canal intake	25.61	233	Hendricks Bridge	20.89	266
8	Hendricks Bridge	20.89	266	Walterville Canal return	17.36	288
9	Walterville Canal return	17.36	288	Hayden Bridge	10.87	330
10	Hayden Bridge	10.87	330	Mohawk River	9.66	338
11	Mohawk River	9.66	338	Coburg bridge	3.24	379
12	Coburg bridge	3.24	379	mouth	0.00	399

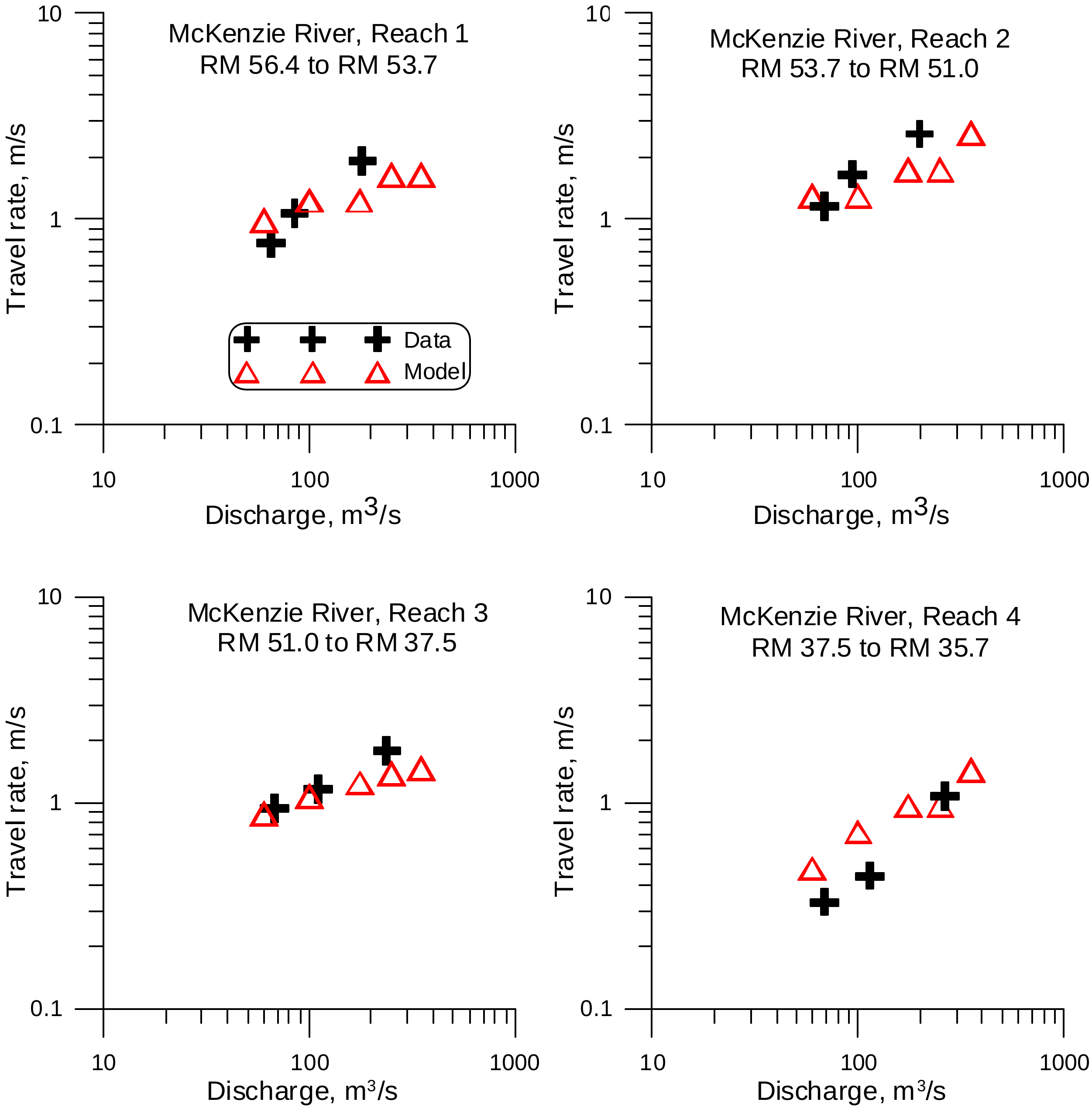

Figure 357: Time of travel study on the McKenzie River, Reaches 1 to 4 (Harris, 1968)

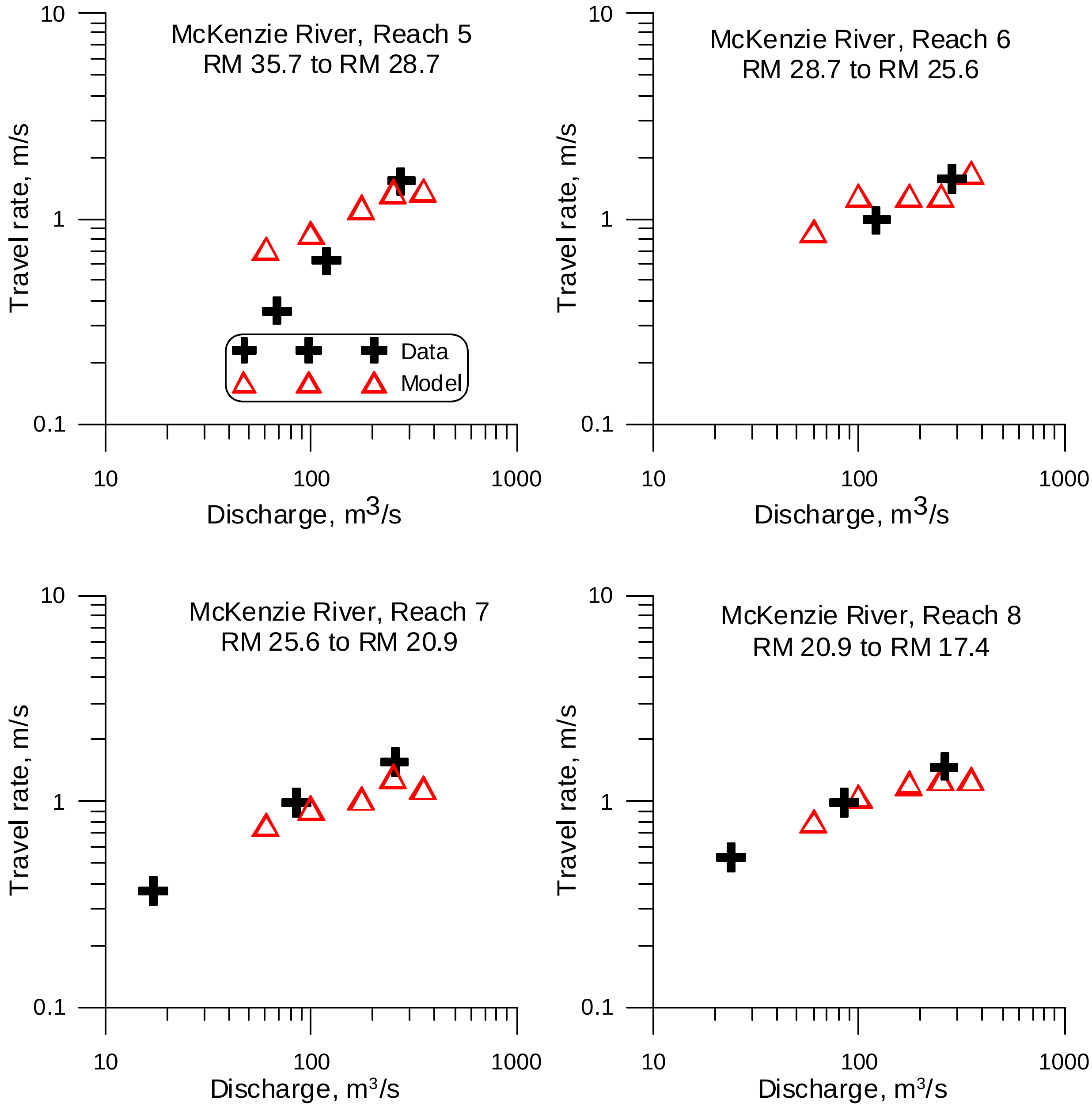

Figure 358: Time of travel study on the McKenzie River, Reaches 5 to 8 (Harris, 1968)

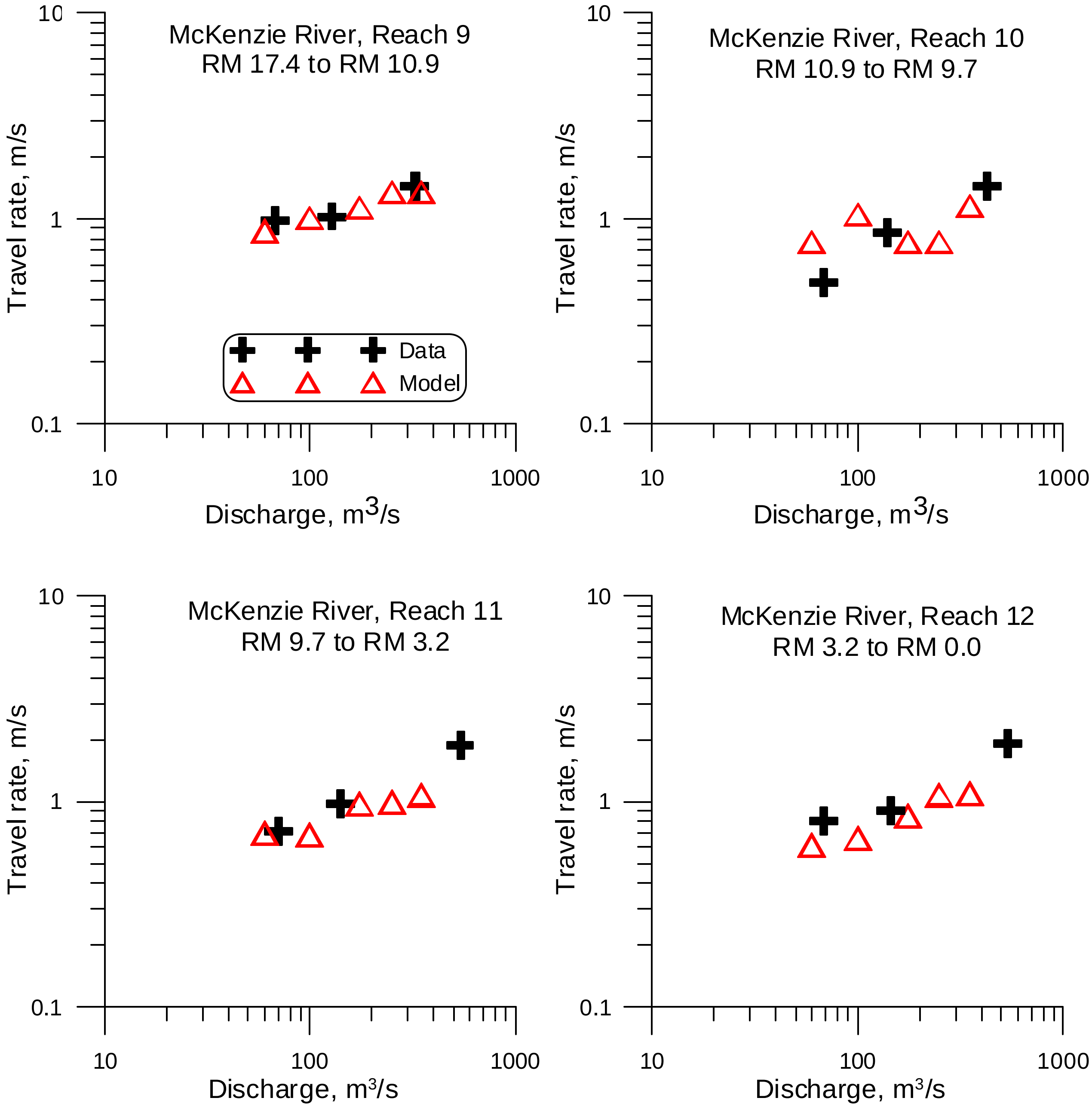

Figure 359: Time of travel study on the McKenzie River, Reaches 9 to 12 (Harris, 1968)

Water Temperature

Water temperature was calibrated using continuous temperature data recorded every half hour or hour at several locations in the basin. Additionally model-data comparisons were made both at small time scales and at larger time scales over the simulation period to ensure diurnal fluctuations were simulated accurately. Calibration parameters included adjusting the Manning's friction factor, channel widths, wind sheltering, evaporation, and sediment temperatures. Vegetative and topographic shade characteristics were not adjusted since the model input was developed using a detailed GIS analysis.

The McKenzie River basin has fourteen sites where continuous temperatures were recorded for calibrating the model. Figure 360 shows a map of the basin with the gage site locations and Table 56 shows a list of the gage sites with RM and corresponding model segment.

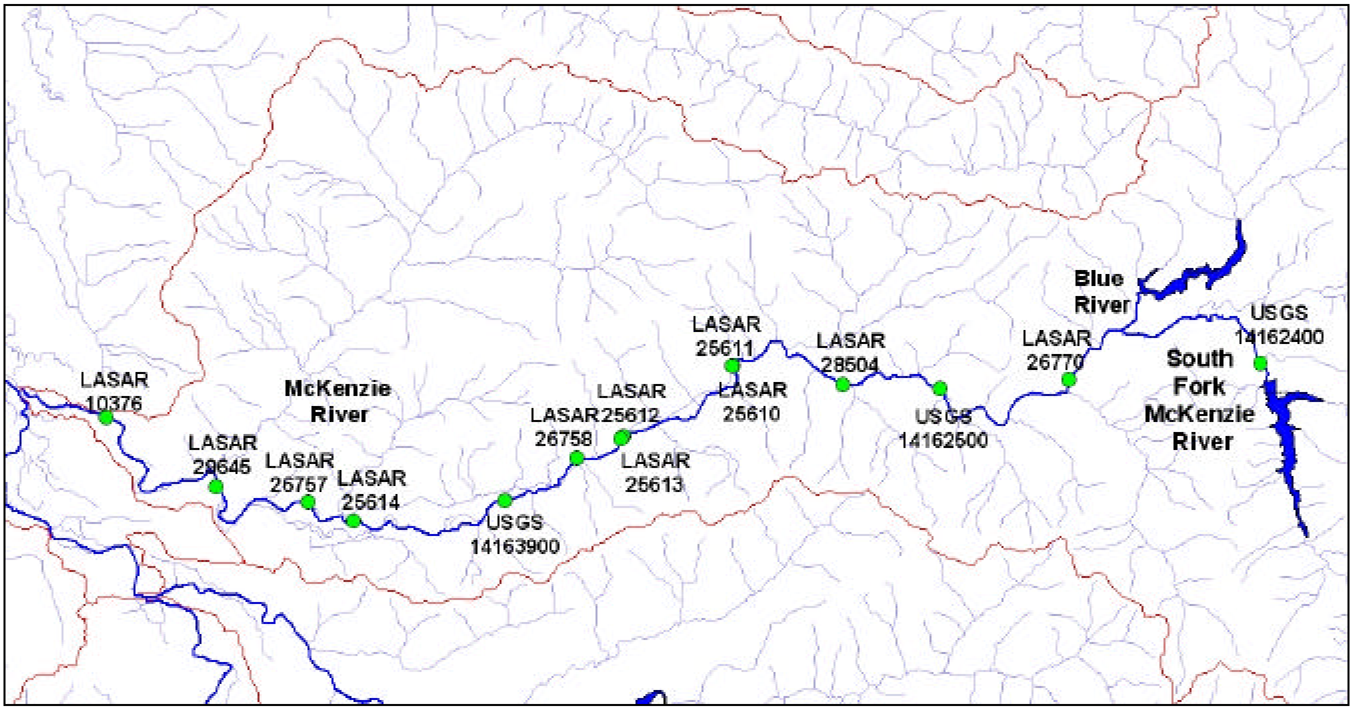

Figure 360: McKenzie River temperature calibration site locations

Table 56: McKenzie River temperature calibration sites

Site ID	Site Description	RM	Model Segment
USGS 14159500	South Fork McKenzie below Cougar Dam	60.39	4
LASAR 26770	McKenzie River below Cougar River	50.99	65
USGS 14162500	McKenzie River near Vida, OR	44.56	108
LASAR 28504	McKenzie River at Helfrich boat ramp - 1.8 mi upstream of Gate Creek	40.74	132
LASAR 25610	McKenzie River below Leaburg Dam	35.72	167
LASAR 25612	McKenzie River above the Leaburg tailrace	30.38	203
LASAR 26758	McKenzie River at Deerborn	28.45	215
USGS 14163900	McKenzie River near Walterville, OR	24.97	240
LASAR 25614	McKenzie River above Walterville Tailrace	17.90	285
LASAR 26757	McKenzie River at Bellinger Landing	15.61	299
LASAR 29645	McKenzie River above Mohawk River	10.40	333
LASAR 10376	McKenzie River at Coburg Rd	3.38	378
LASAR 25611	US end of Leaburg Canal, Intake	35.78	402
LASAR 25613	Leaburg Canal, Powerhouse Tailrace	30.27	431

The model was calibrated by comparing the continuous temperature data and model results but since the model will be used for running model scenarios examining the daily maximum temperature model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

Temperatures on the McKenzie River were calibrated from May to October 2001. Table 57 lists the model-data error statistics for continuous temperature model results and data. The table shows absolute mean errors (AME) of less than 1 ^{o}C and root mean square error (RMS) of less than 1.20 ^{o}C. Overall the mean error shows there is slight bias on the cooler side of about 0.5 ^{o}C.

Figure 361 shows a model-data temperature comparison on the South Fork McKenzie below the upstream boundary conditions of the model. Since the site is so close to the upstream boundary the model-data comparison is expected to be close as demonstrated by the error statistics of less than 0.20 ^{o}C. The next downstream site at RM 51, below Cougar River, as shown in Figure 362, indicates close model-data agreement with cooler model temperatures at night in early summer.

Figure 363 shows a model-data temperature comparison on the McKenzie River near Vida, OR (RM 44.6). The model-data temperature comparison shows good agreement. The model is capturing the diurnal swings over the summer.

Figure 364 shows a model-data continuous temperature time series comparison for the McKenzie River just below the Leaburg Canal diversion dam (RM 35.7). At this location the model is showing diurnal fluctuations which are larger than the data is showing with the modeling cooling more at night. The larger temperature variation in the model could be due to the channel bathymetry being simulated at larger widths than seen in the actual river. The pool upstream of the Leaburg Dam may not be characterized as well either due to the lack of bathymetric data. Further refinements to the diversion operations rules may also result in differences in the flow passed downstream over the Leaburg Dam which would also influence the temperature regime. The plot shows there is still relatively good agreement between the model and data.

Figure 365 shows the model-data temperature time series comparison for the McKenzie River just above where the Leaburg canal flow re-enters the river from the powerhouse (RM 30.4). The model results show relatively good agreement with the data over the summer with slightly larger diurnal swings in the model output. These larger swings may be due to the disagreement between the model-data just upstream being introduced and passed downstream and may be due to slightly larger channel widths than river experiences in this reach.

The next monitoring site down is located on the McKenzie River at Deerborn (RM 28.5). Figure 366 shows a model-data temperature time series comparison for this location and indicates that although the model is still showing slightly larger diurnal temperature swings than the data there is still good model-data agreement. Both the model and data show reduced diurnal temperature swings at this location than the upstream location at RM 30.4. These results indicate the model is capturing the physical processes responsible for reducing diurnal temperature swings in this reach.

Figure 367 shows a model-data temperature comparison on the McKenzie River near Walterville which is just below the Walterville Canal Diversion Dam (RM 25). This site also represents the furthest downstream site where river flows are monitored. The figure shows there is relative good model-data agreement but there are periods when the model has diminished diurnal temperature swings compared to the data. Similar to the Leaburg Canal diversion this could be due to uncertainties in the channel bathymetry above or below the diversion dam or the flows passed downstream over the dam.

Figure 368 shows a model-data temperature comparison on the McKenzie River above where the Walterville canal flow re-enters the river (RM 17.9). The figure shows there is good model-data agreement between the two temperature time series curves. The model is capturing the diurnal cycle of temperatures well with only small deviations of warmer or cooler temperatures compared to data. This site is 7 miles downstream from the site above where there was less model-data agreement. During the travel time the effects of the diversion dam on temperature have less influence as other physical processes affecting temperature increase in dominance.

In 2001 the furthest downstream location monitored for temperature and used for comparing with model results was at the Bellinger Landing along the McKenzie River at RM 15.6. Figure 369 shows model-data temperature time series comparison for this site. The figure indicates there is relatively good agreement between the model and data with a few time periods when the model daily peaks are not quite as warm as the data suggests. This discrepancy could be due to uncertainties the river channel bathymetry which is resulting in underestimation of channel width or uncertainties in the river channel flow since there are downstream gage stations to judge whether water is being lost to the system.

In addition to the temperature monitoring along the McKenzie River in 2001 there were temperatures recorded at the upstream and downstream end of the Leaburg Canal. Figure 370 shows the model-data temperature comparison at the upstream end of the Leaburg Canal just after the water is diverted from the McKenzie River. This figure shows there is relatively good model-data agreement but that the model tends to be cooler each night with larger diurnal temperature swings. This discrepancy could be due to uncertainties associated with the river channel bathymetry upstream of the dam or the diversion operations. The results are similar to the model results shown just below the Leaburg diversion Dam in Figure 364. Figure 371 shows the model temperature results and data at the downstream end of the Leaburg Canal. This figure indicates the model is capturing the daily peak temperatures but is missing the diminished diurnal temperature swings. This may be due to uncertainties in simulating the diversion canal where there was no bathymetric data available.

Table 57: McKenzie River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
USGS 14159500	60.39	4	6982	0.06	0.10	0.16
LASAR 26770	50.99	65	6638	-0.37	0.57	0.65
USGS 14162500	44.56	108	7104	-0.42	0.53	0.62
LASAR 28504	40.74	132	No data			
LASAR 25610	35.72	167	5711	-0.43	0.71	0.85
LASAR 25612	30.38	203	5715	-0.25	0.72	0.86
LASAR 26758	28.45	215	4678	-0.34	0.65	0.80
USGS 14163900	24.97	240	3284	-0.38	0.61	0.76
LASAR 25614	17.90	285	5709	-0.31	0.61	0.74

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
LASAR 26757	15.61	299	4825	-0.44	0.66	0.81
LASAR 29645	10.40	333	No data			
LASAR 10376	3.38	378	No data			
LASAR 25611	35.78	402	5712	-0.37	0.65	0.77
LASAR 25613	30.27	431	5714	-0.59	0.81	0.99

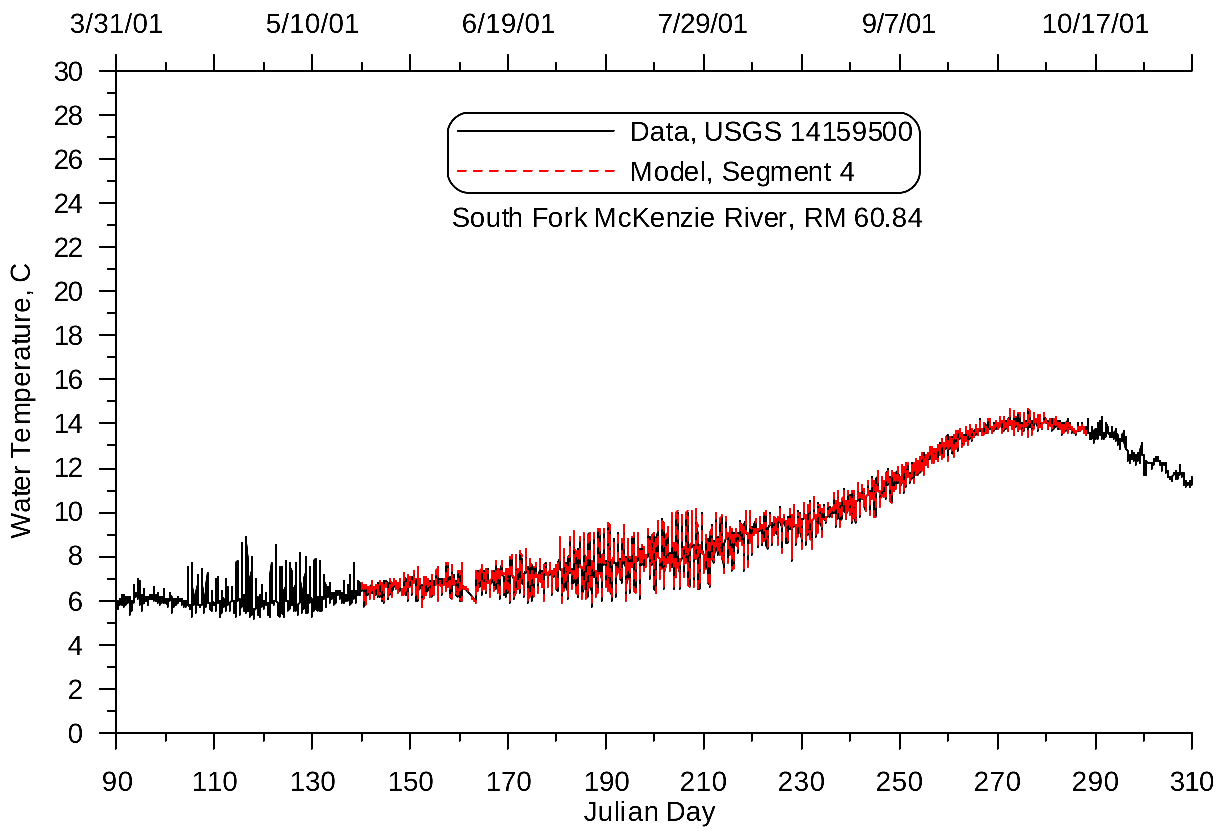

Figure 361: South Fork McKenzie River below Cougar Dam model-data continuous temperature comparison, 2001

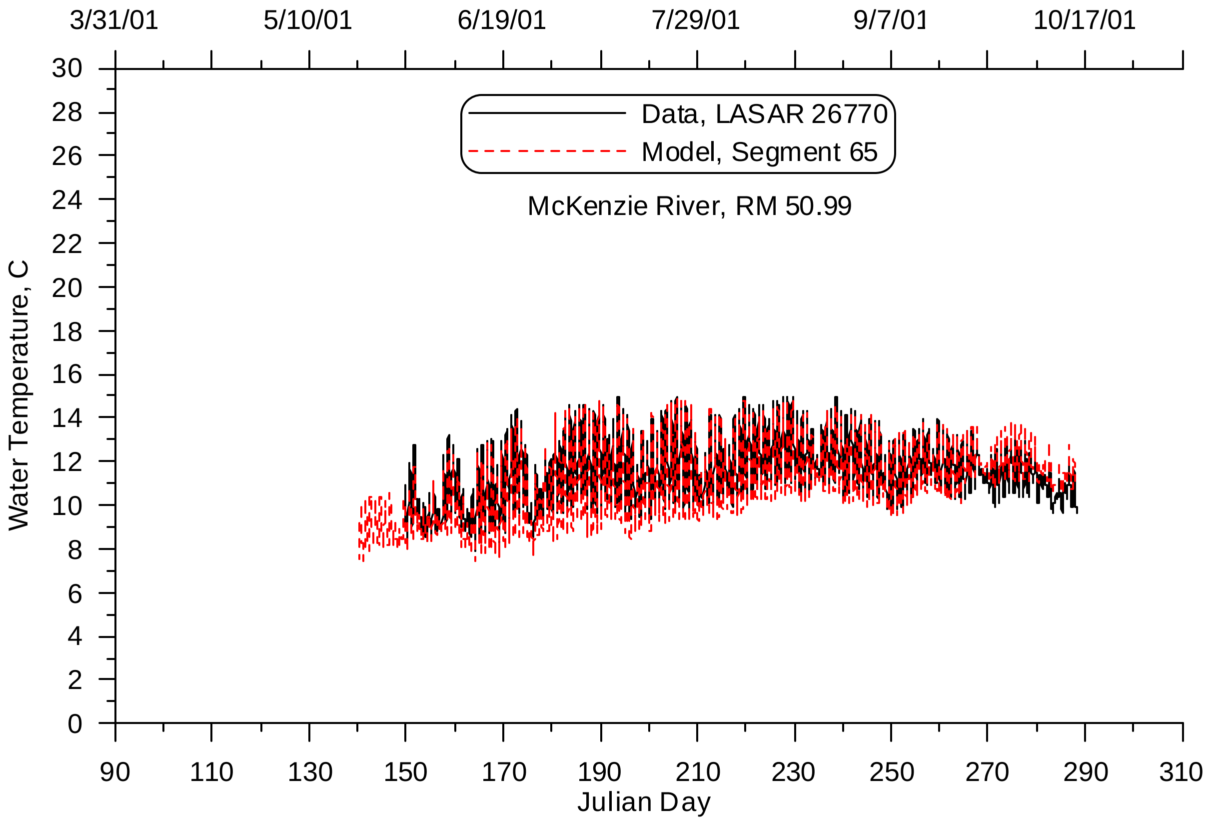

Figure 362: McKenzie River below Cougar River model-data continuous temperature comparison, 2001

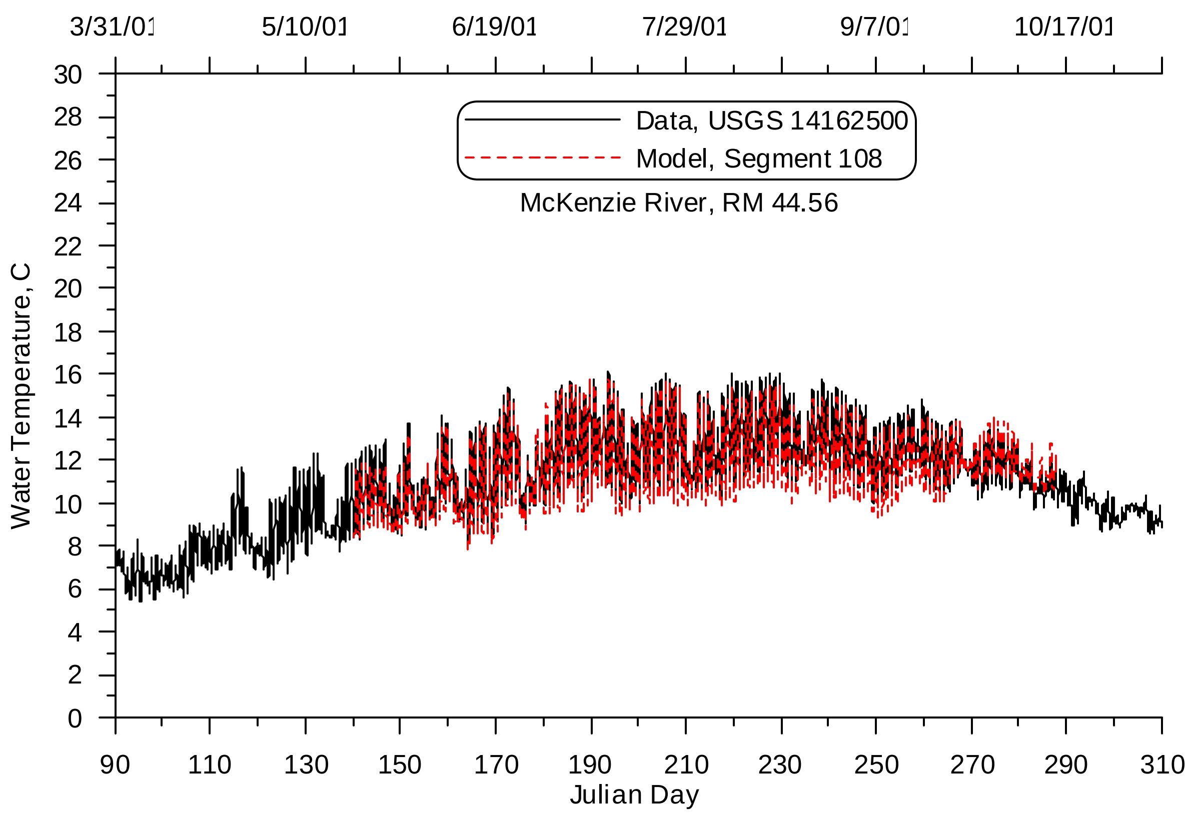

Figure 363: McKenzie River near Vida model-data continuous temperature comparison, 2001

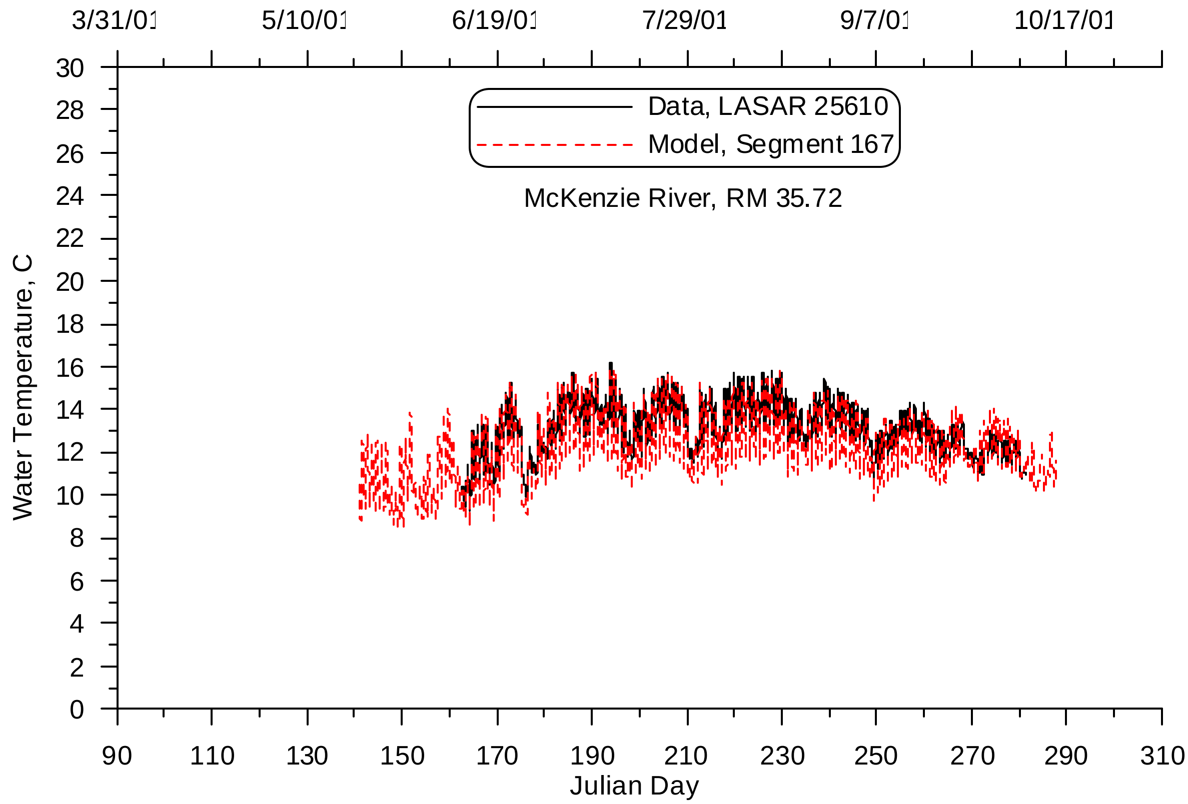

Figure 364: McKenzie River below Leaburg Dam model-data continuous temperature comparison, 2001

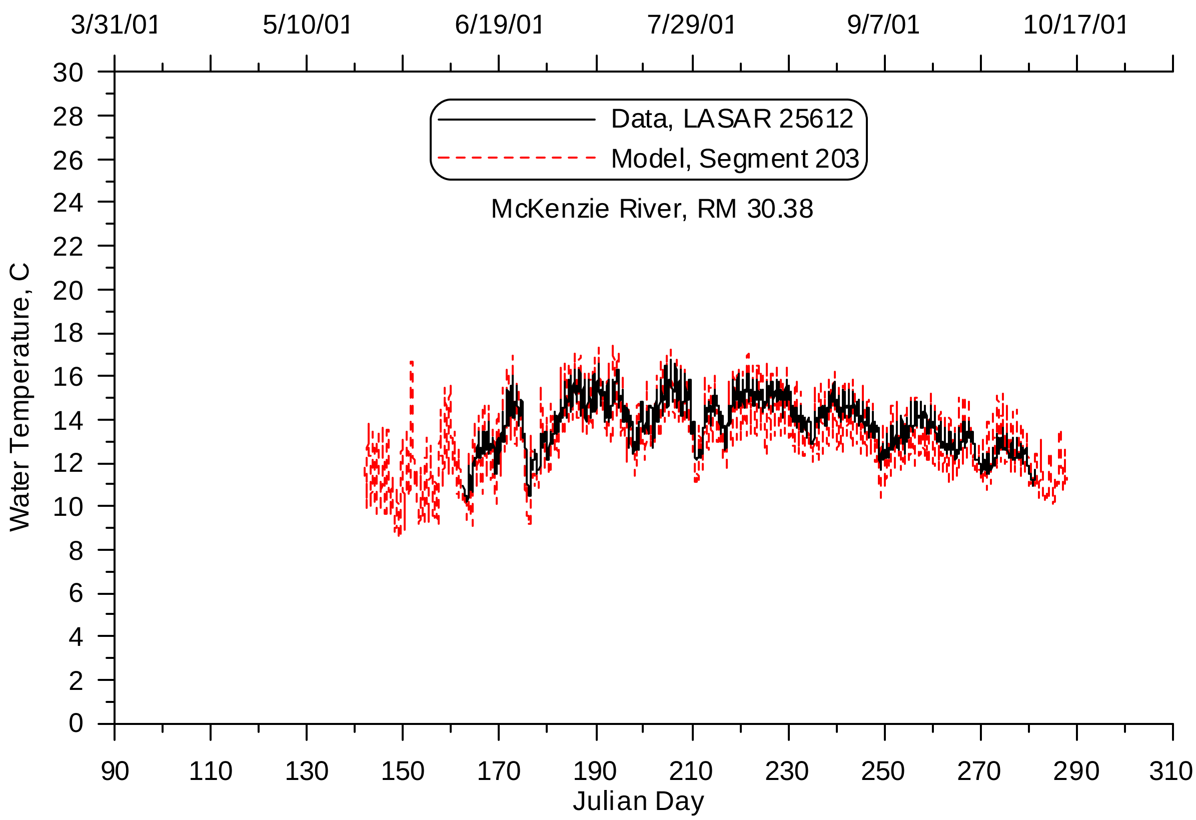

Figure 365: McKenzie River above the Leaburg tailrace model-data continuous temperature comparison, 2001

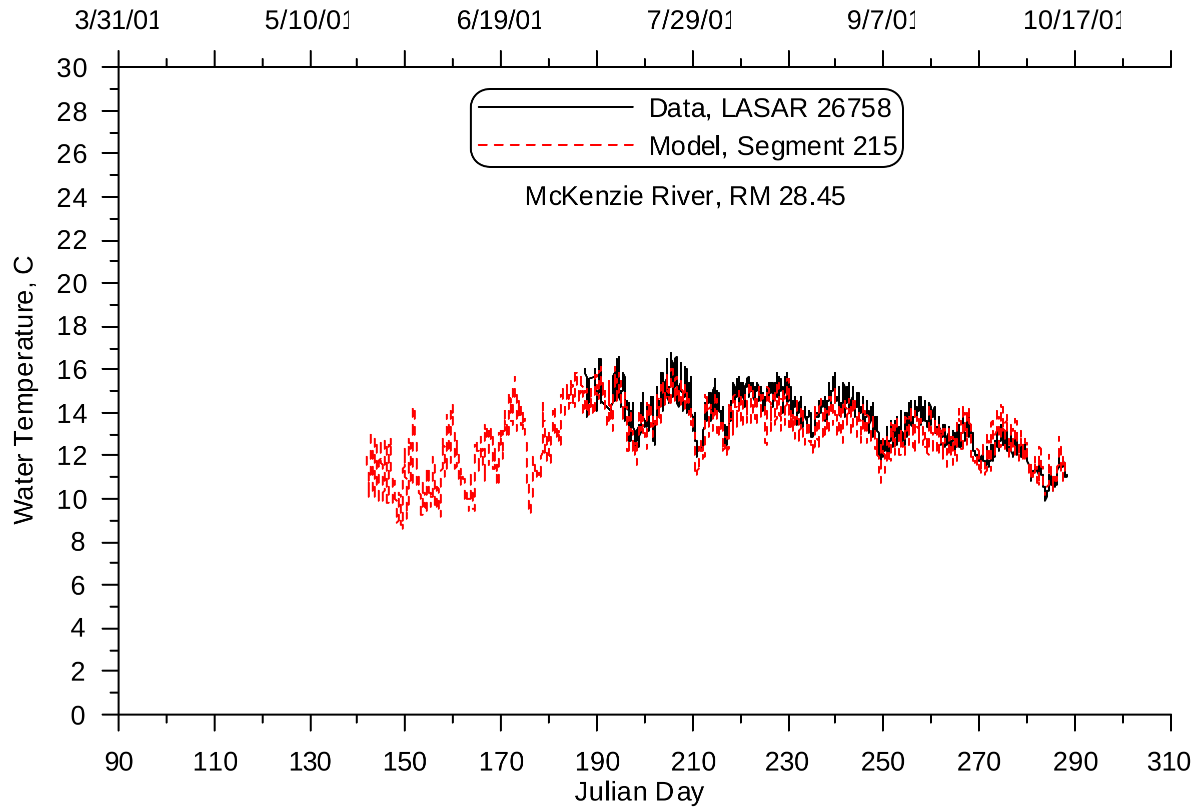

Figure 366: McKenzie River at Deerborn model-data continuous temperature comparison, 2001

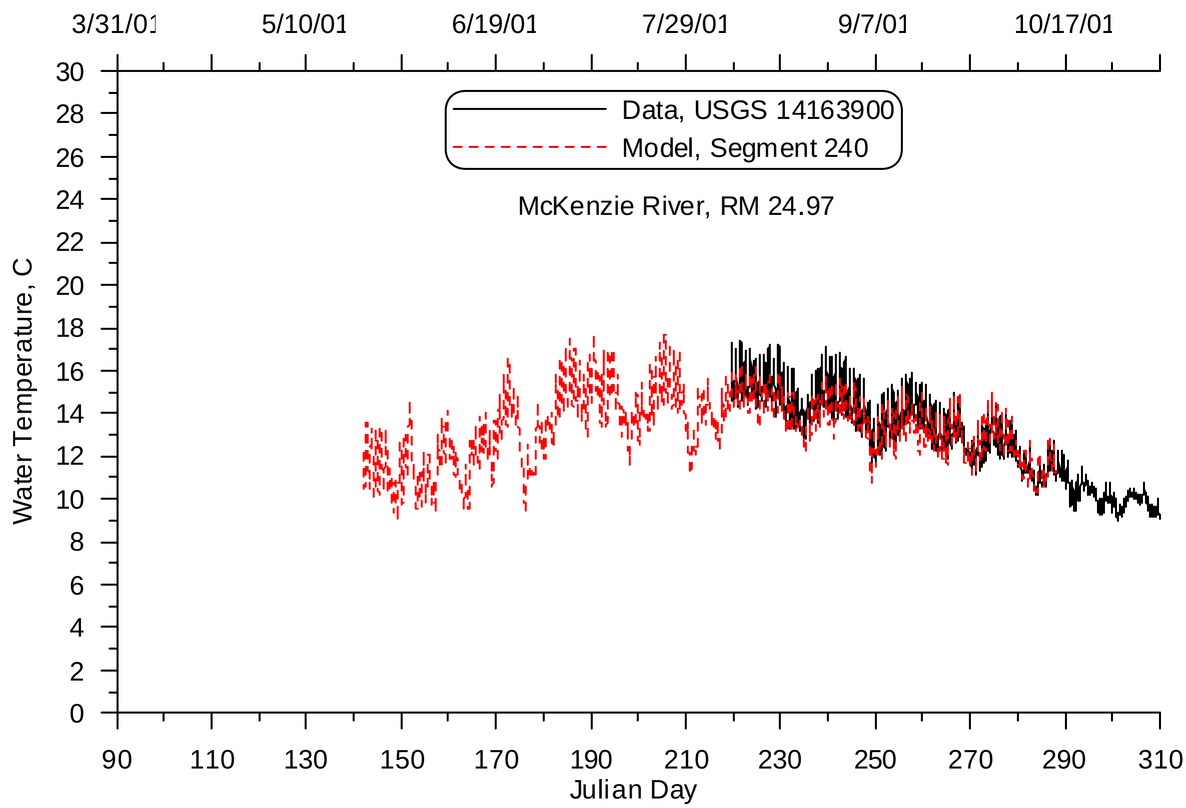

Figure 367: McKenzie River near Walterville model-data continuous temperature comparison, 2001

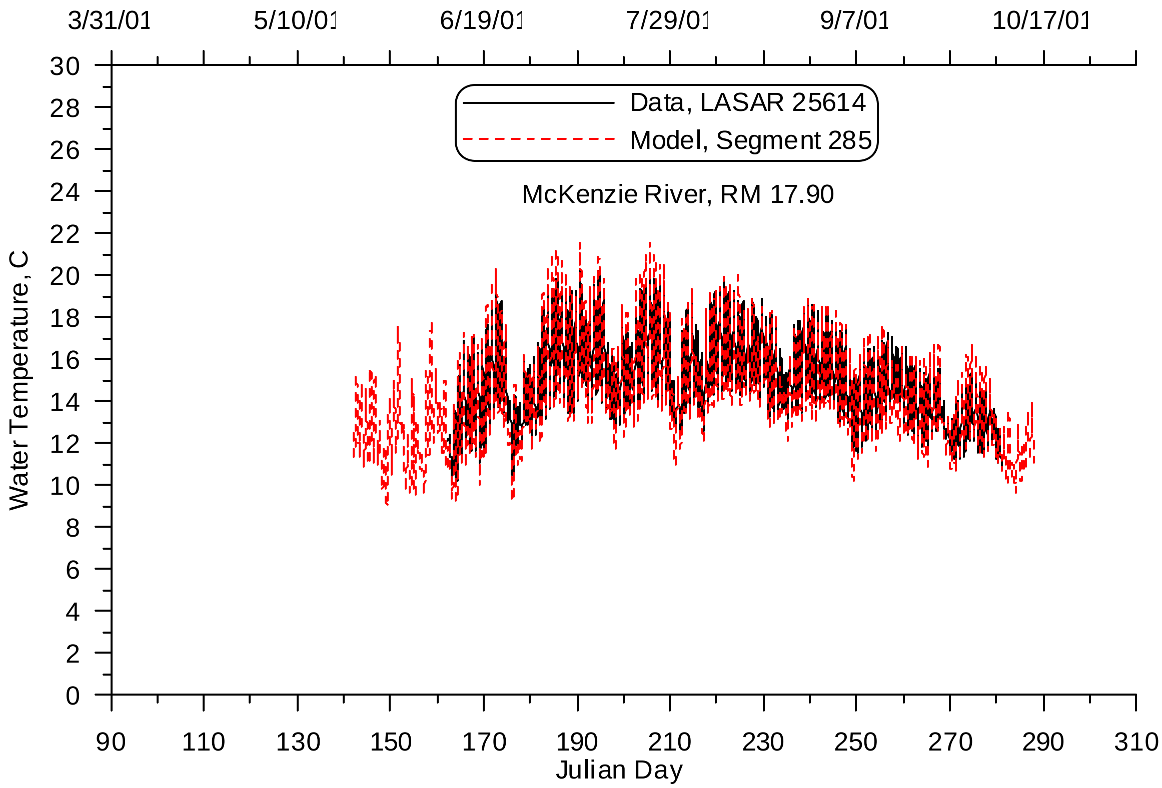

Figure 368: McKenzie River above Walterville Tailrace model-data continuous temperature comparison, 2001

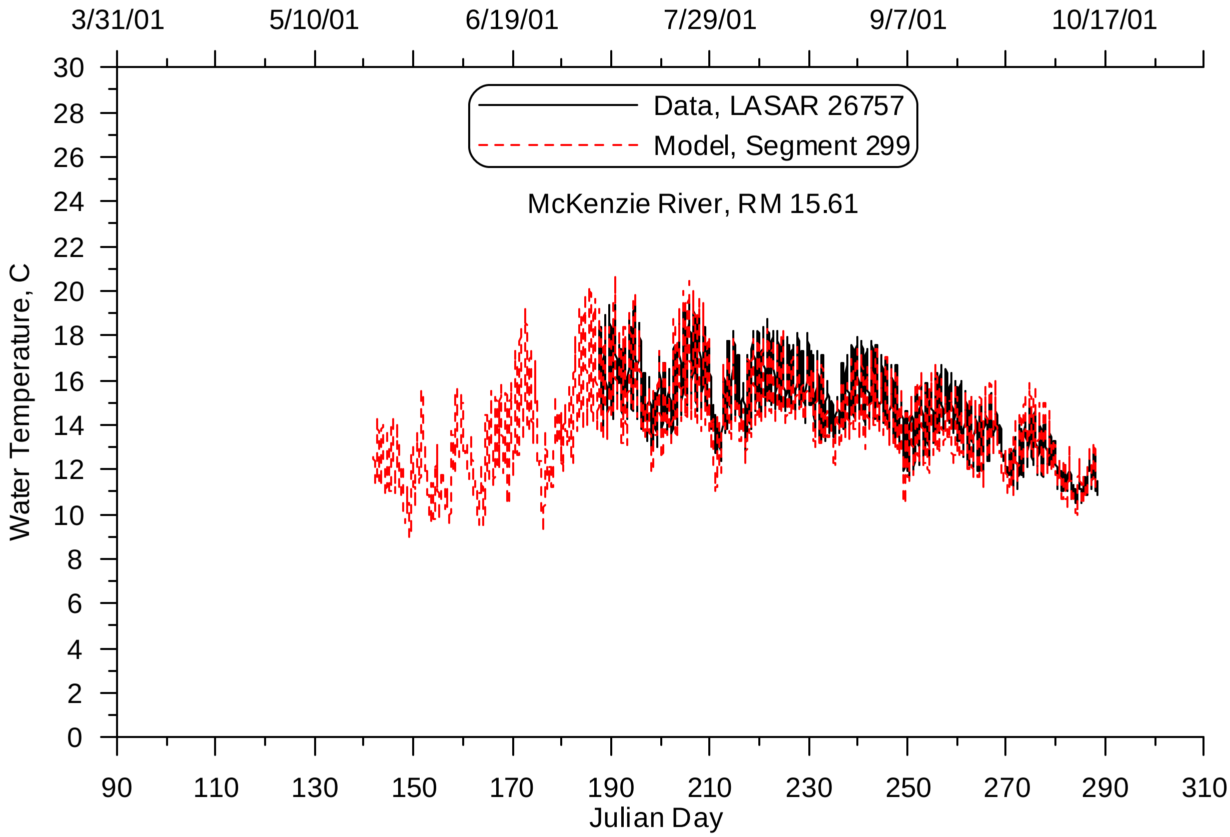

Figure 369: McKenzie River at Bellinger Landing model-data continuous temperature comparison, 2001

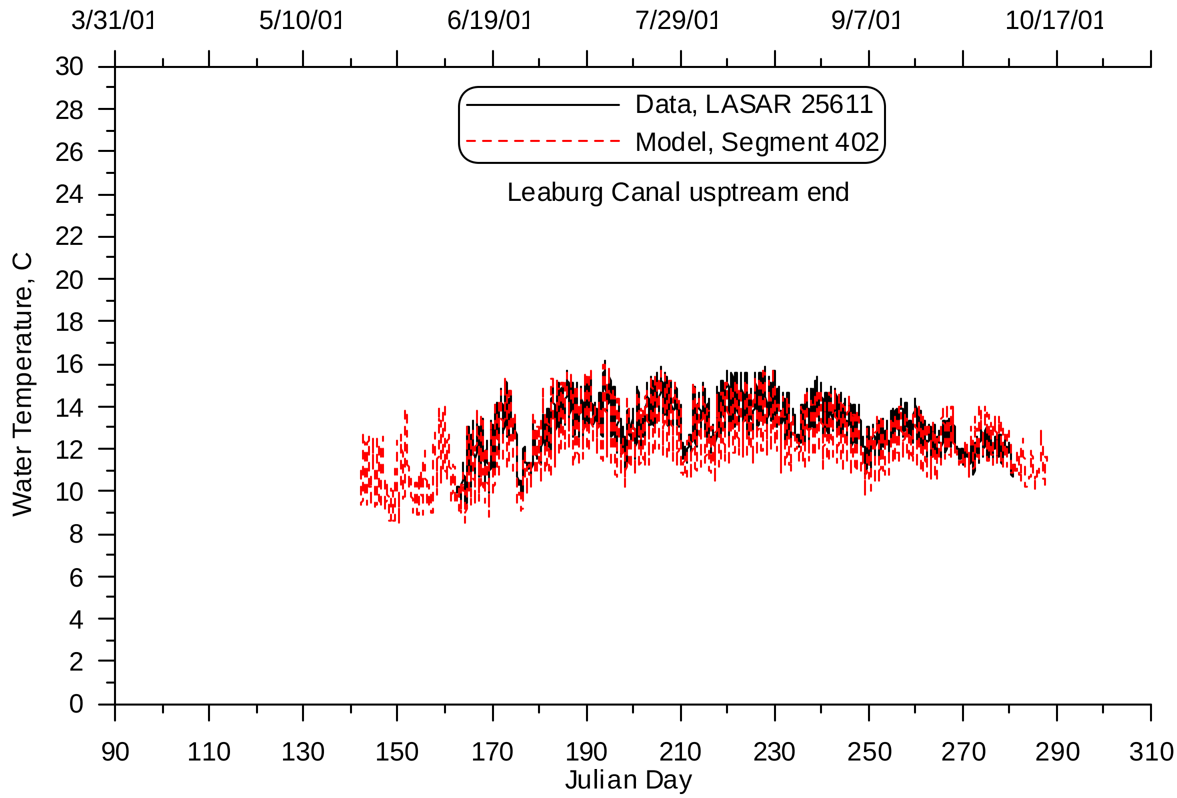

Figure 370: Leaburg Canal Intake, upstream end model-data continuous temperature comparison, 2001

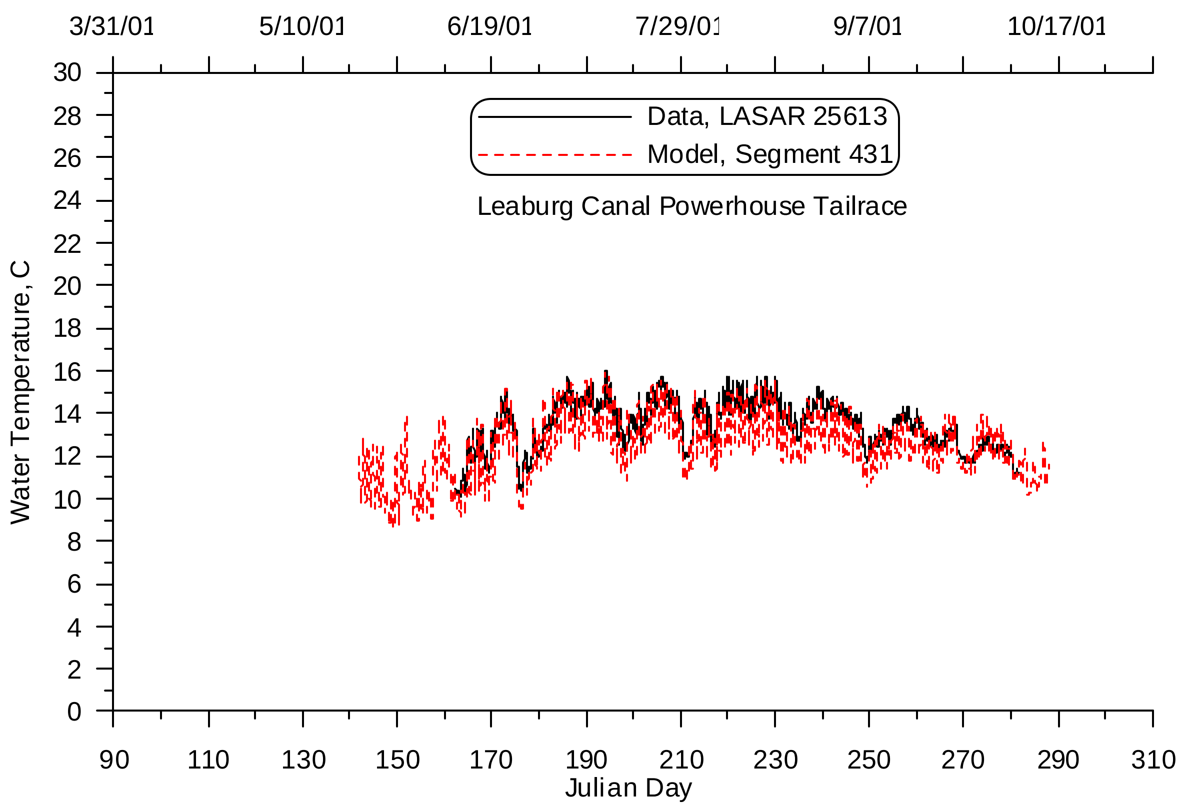

Figure 371: Leaburg Canal Powerhouse Tailrace, downstream end model-data continuous temperature comparison, 2001

Year 2002

Temperatures on the McKenzie River were calibrated from April to the end of October 2002. Table 58 lists the model-data error statistics for continuous temperature. The table shows absolute mean errors (AME) and root mean square error (RMS) of less than 1 ^{o}C. Overall the mean error shows there is slight bias on the warmer side of about 0.2 ^{o}C.

Figure 372 shows a model-data temperature comparison on the South Fork McKenzie below the upstream boundary conditions of the model. Since the site is so close to the upstream boundary the model-data comparison is expected to be close as demonstrated by the error statistics of less than 0.20 ^{o}C. The next downstream site at RM 51, below Cougar River, as shown in Figure 373, indicates close model-data agreement with the model closely matching the data through diurnal temperature swings.

Figure 374 shows a model-data temperature comparison on the McKenzie River near Vida, OR (RM 44.6). The model-data temperature comparison shows good agreement. The model is capturing the diurnal swings over the summer but appear to be slightly too warm in early to middle summer. The model-error statistics are still within 0.50 ^{o}C.

Figure 375 shows a model-data temperature time series comparison for the McKenzie River at the Helfrich boat ramp at RM 40.7. Similar to the site upstream at RM 44.6 the model is showing slightly warmer temperatures in the early to middle summer than the data. This warmer period at this site may be solely due to the warmer results upstream. The model results are still in good agreement with data with RMS error of 0.5 ^{o}C.

Figure 376 shows a model-data temperature time series comparison for the McKenzie River just below the Leaburg Canal diversion dam (RM 35.7). The model is showing diurnal fluctuations which are larger than the data which could be due to the uncertainties in the channel bathymetry above and below the dam and the flow diversion operations discussed for 2001. The plot shows there is still relatively good agreement between the model and data.

The next monitoring site down is located on the McKenzie River at Deerborn (RM 28.5). Figure 377 shows a model-data temperature time series comparison and indicates there is good model-data agreement over the summer with the model having a few higher peak temperatures. Both the model and data show reduced diurnal temperature swings compared to the upstream location at RM 35.7.

Figure 378 shows a model-data temperature comparison on the McKenzie River near Walterville which is below the Walterville Canal Diversion Dam (RM 25). The figure shows there is relative good model-data agreement but there are periods when the model has diminished diurnal temperature swings compared to the data. This is similar to the results seen in 2001 and may be due to uncertainties in the channel bathymetry above or below the diversion dam or the flows passed downstream over the dam. In the summer of 2002 there was no water diverted into the Walterville canal so all water was passed downstream to the river.

The next monitoring site downstream for comparing with model results was at the Bellinger Landing along the McKenzie River at RM 15.6. Figure 379 shows model-data temperature time series comparison for this site. The figure indicates there is relatively good agreement between the model and data with the modeling following the diurnal temperature swings. There are a few periods when the night-time low temperatures are cooler than data but the day-time peaks are similar to data. Similar to 2001 model results the model deviations from data could be due to uncertainties the river channel bathymetry or flow since there are downstream gage stations to judge whether water is being lost to the system.

In 2002 there were two additional sites where stream temperatures were monitored below RM 15.6. There was a monitoring site at RM 10.4 which is above where the Mohawk River enters the McKenzie River. Figure 380 shows a model-data comparison plot of temperature and indicates thee is good agreement between the two. Root mean square error between the model and data is 0.7 ^{o}C. The second site added in 2002 was at RM 3.4, near Coburg Rd. Figure 381 Shows a model-data comparison plot and indicates there is relatively good agreement between the model and data. There are brief periods when the model results show diurnal temperature swings slightly larger than the data. This site also has a RMS error between the model and data of 0.7 ^{o}C.

Similar to the monitoring in 2001, water temperatures were recorded at the upstream and downstream ends of the Leaburg Canal. Figure 382 shows the model-data temperature comparison at the upstream end of the Leaburg Canal just after the water is diverted from the McKenzie River. This figure shows there is relatively good model-data agreement but that the model tends to have larger diurnal temperature swings. This discrepancy could be due to uncertainties associated with the river channel bathymetry upstream of the dam or the diversion operations. Figure 383 shows the model temperature results and data at the downstream end of the Leaburg Canal. This figure indicates the model still has larger diurnal temperature swings than the data, which may be partially due to the upstream end of the canal having larger temperature swings. Additionally, this may be due to uncertainties in simulating the diversion canal where there was no bathymetric data available.

Table 58: McKenzie River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14159500	60.39	4	10271	0.04	0.10	0.16
LASAR 26770	50.99	65	5856	-0.13	0.32	0.39
USGS 14162500	44.56	108	10270	0.33	0.40	0.50
LASAR 28504	40.74	132	3385	0.34	0.40	0.50
LASAR 25610	35.72	167	5668	0.28	0.58	0.73
LASAR 25612	30.38	203	No data			
LASAR 26758	28.45	215	5666	0.16	0.57	0.71
USGS 14163900	24.97	240	10270	0.15	0.47	0.60
LASAR 25614	17.90	285	No data			
LASAR 26757	15.61	299	4870	-0.03	0.42	0.53
LASAR 29645	10.40	333	5857	-0.09	0.52	0.64
LASAR 10376	3.38	378	5715	0.07	0.51	0.63
LASAR 25611	35.78	402	5669	0.40	0.59	0.76
LASAR 25613	30.27	431	5667	0.14	0.62	0.76

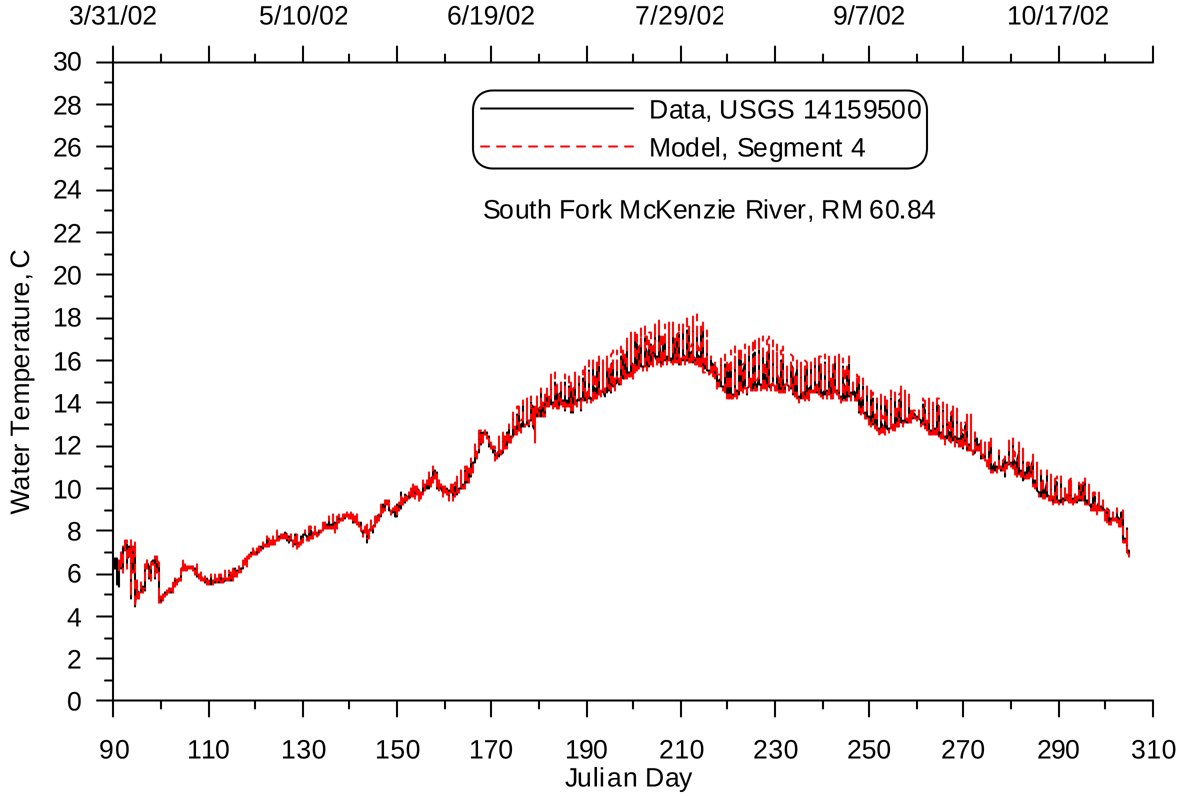

Figure 372: South Fork McKenzie below Cougar Dam model-data continuous temperature comparison, 2002

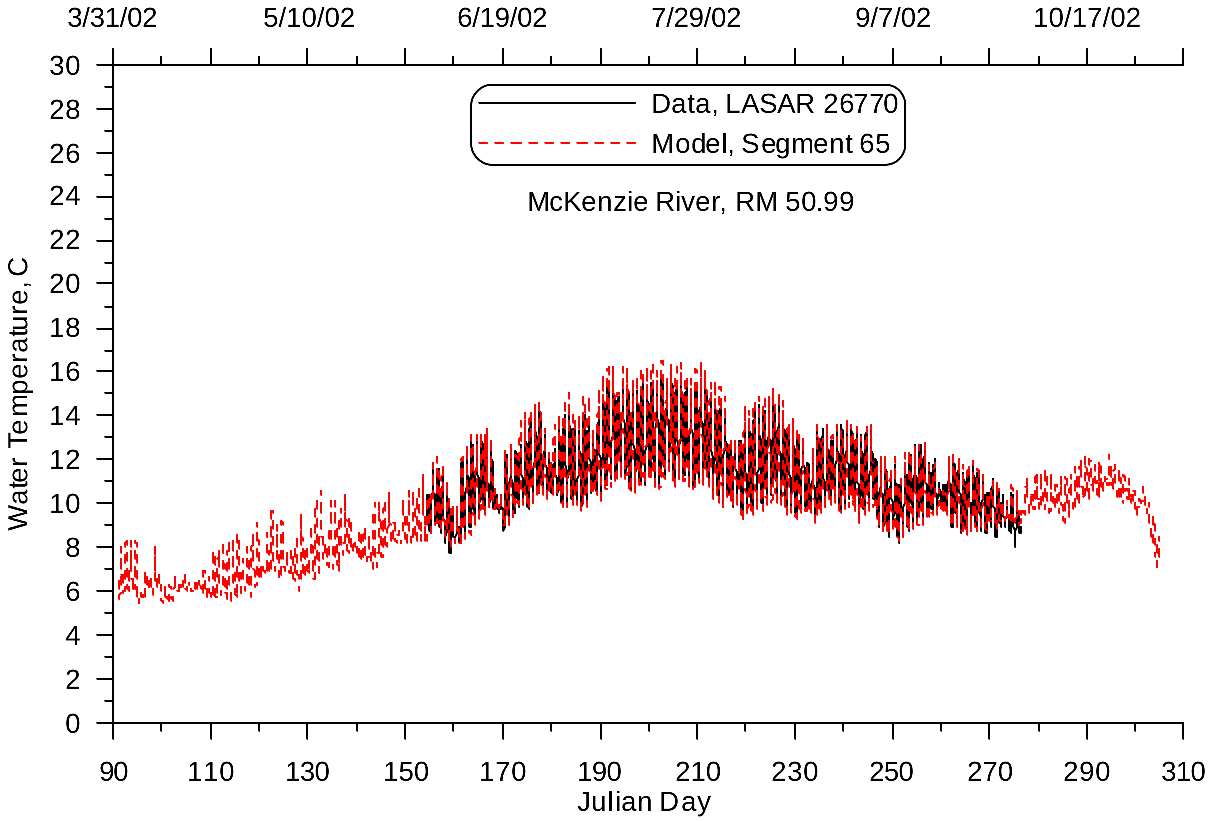

Figure 373: McKenzie River below Cougar River model-data continuous temperature comparison, 2002

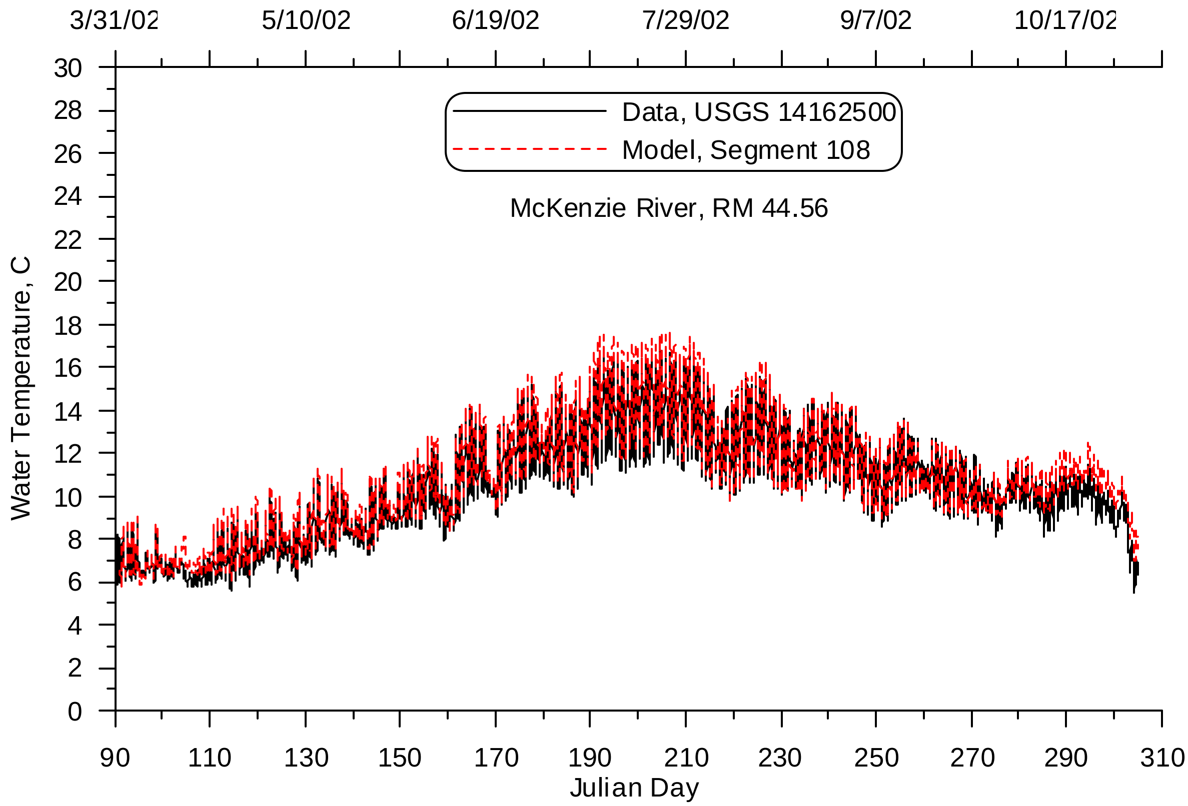

Figure 374: McKenzie River near Vida model-data continuous temperature comparison, 2002

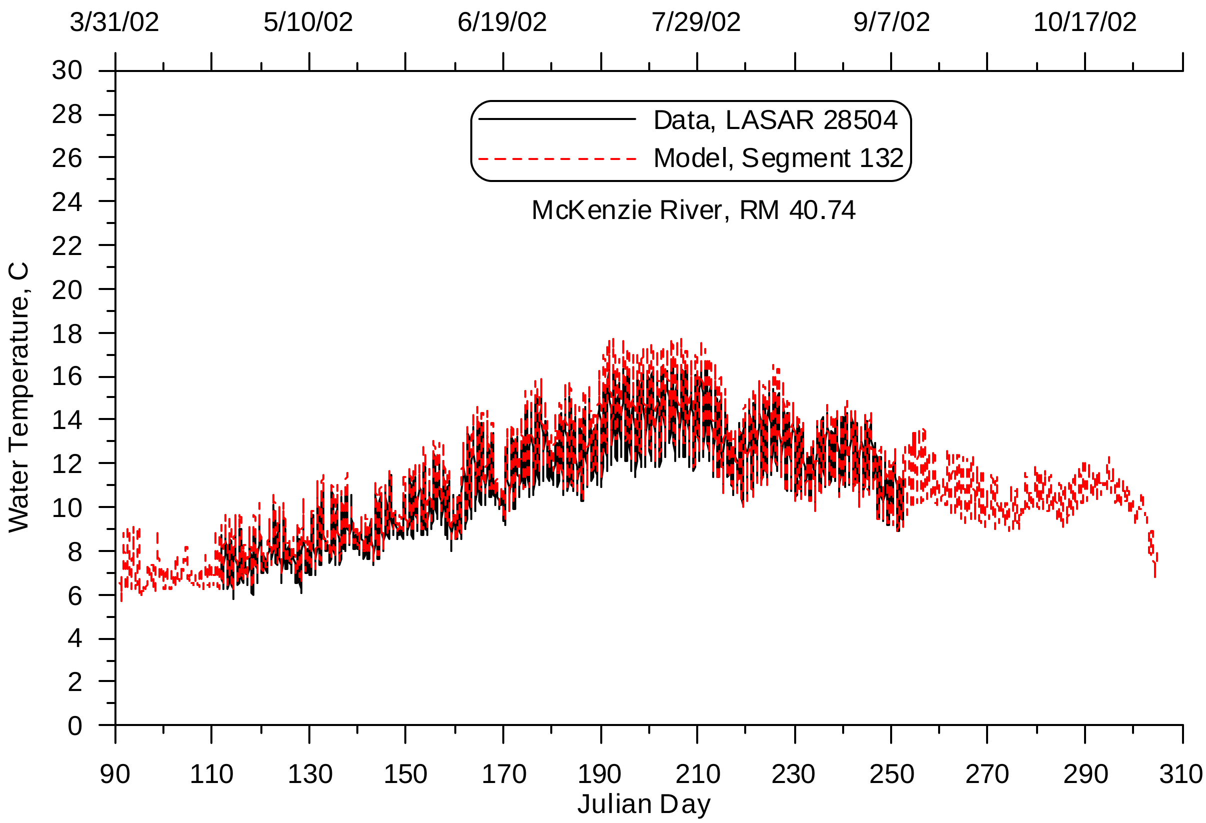

Figure 375: McKenzie River at Helfrich boat ramp model-data continuous temperature comparison, 2002

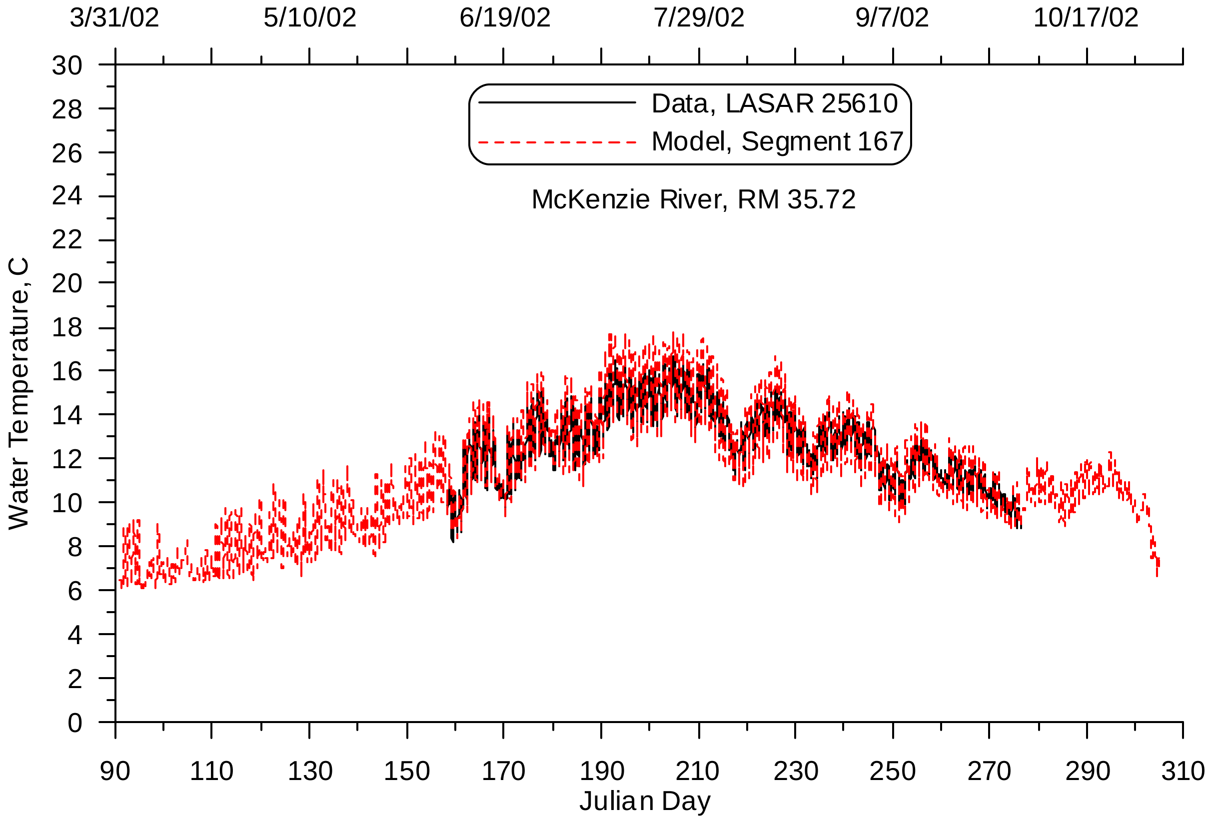

Figure 376: McKenzie River below Leaburg Dam model-data continuous temperature comparison, 2002

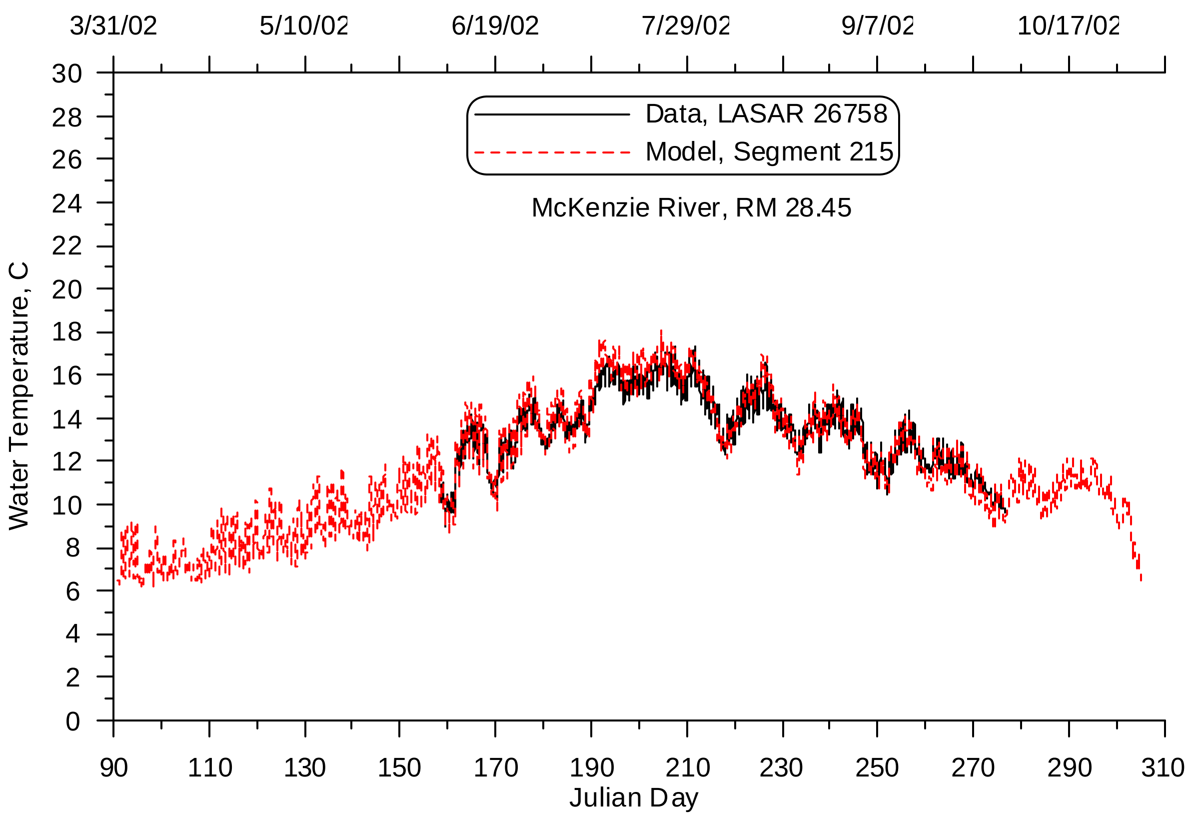

Figure 377: McKenzie River at Deerborn model-data continuous temperature comparison, 2002

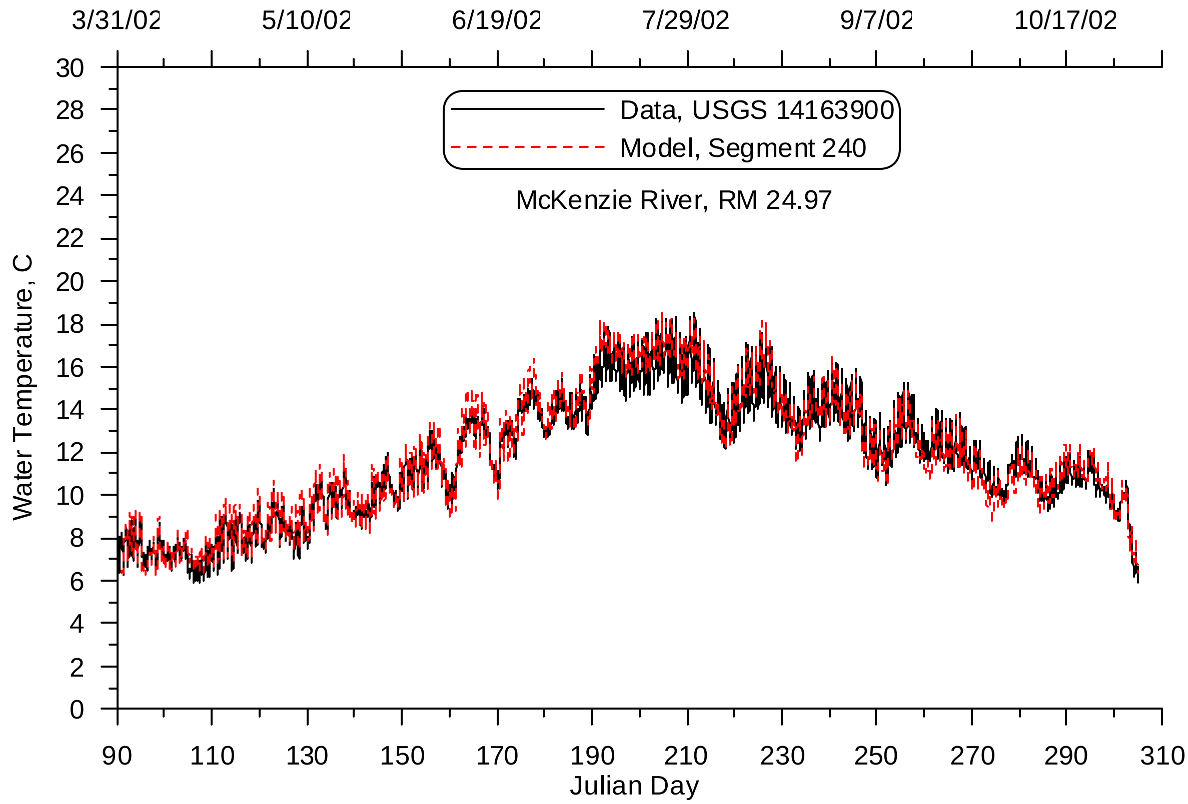

Figure 378: McKenzie River near Walterville model-data continuous temperature comparison, 2002

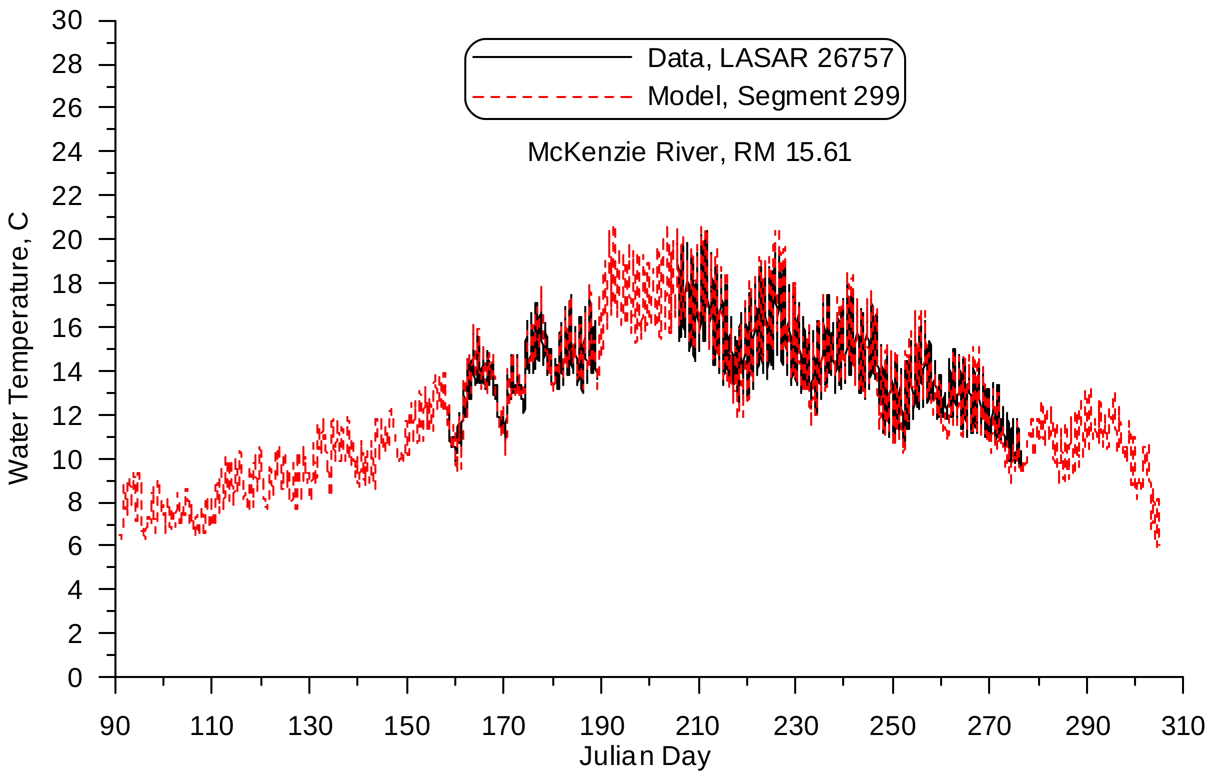

Figure 379: McKenzie River at Bellinger Landing model-data continuous temperature comparison, 2002

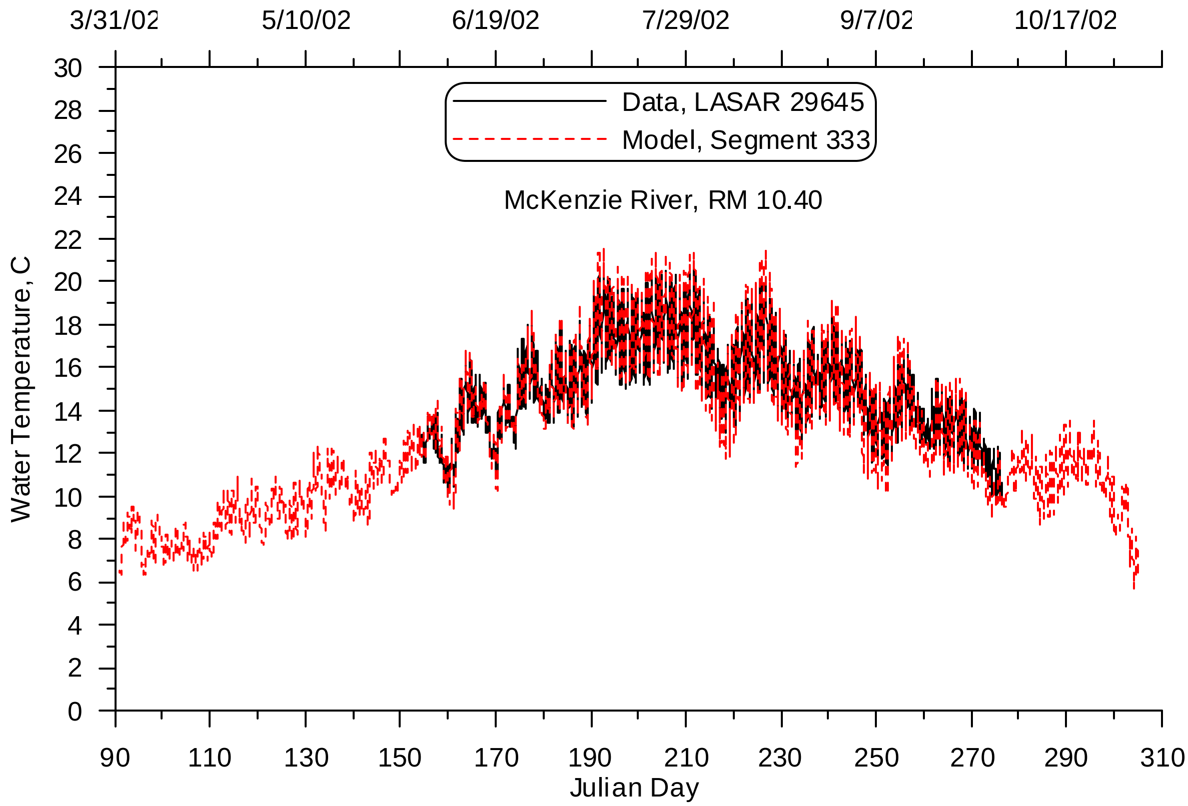

Figure 380: McKenzie River above Mohawk River model-data continuous temperature comparison, 2002

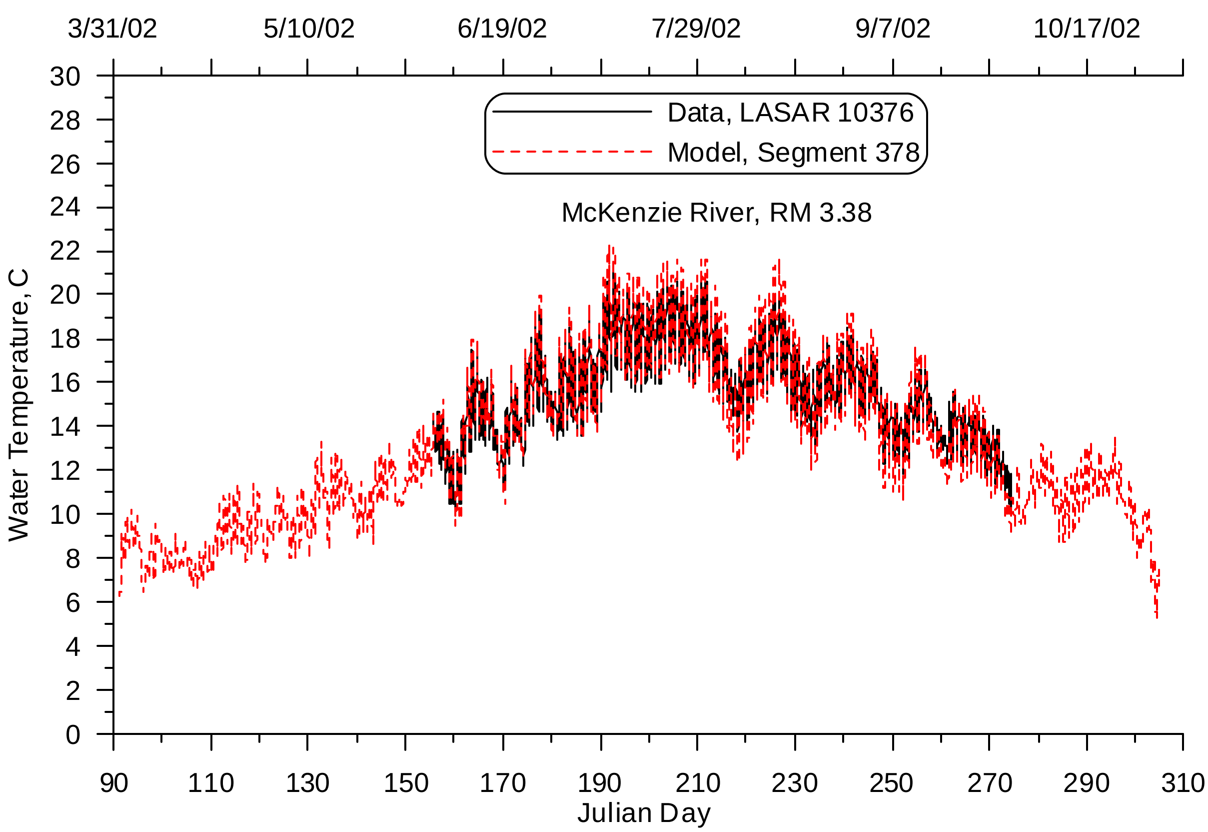

Figure 381: McKenzie River at Coburg Rd model-data continuous temperature comparison, 2002

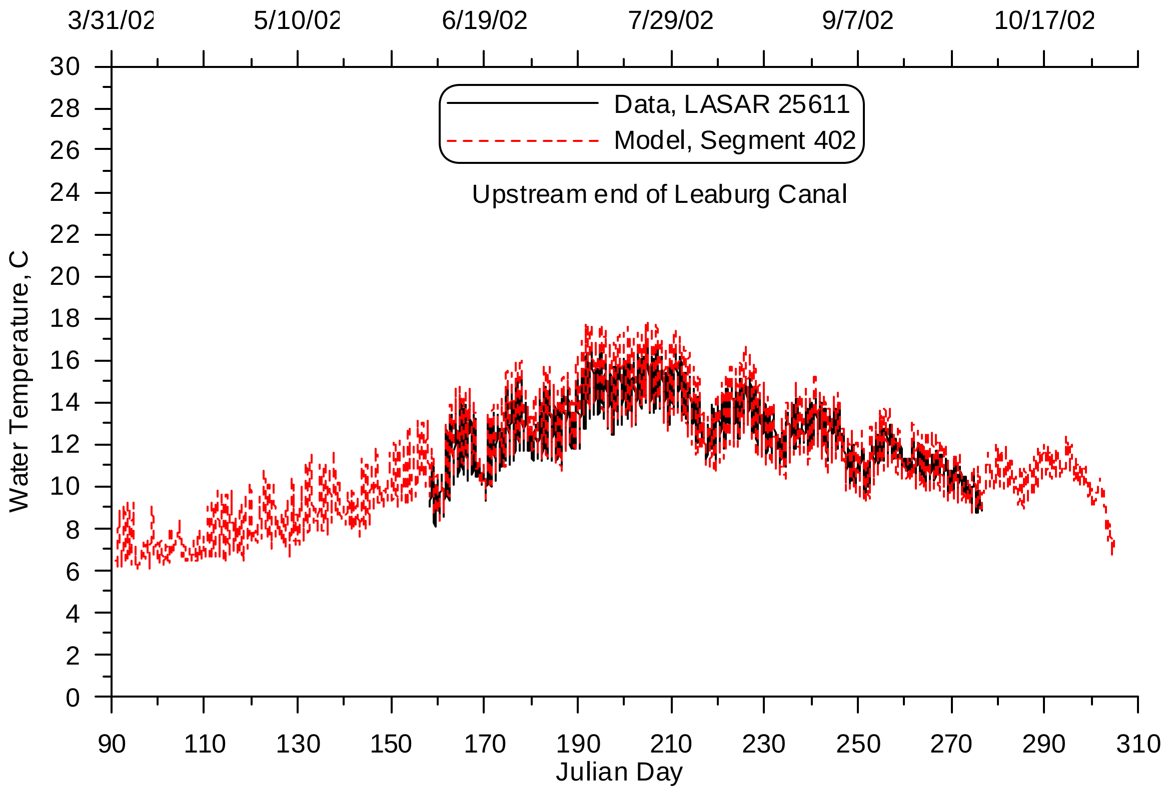

Figure 382: Leaburg Canal Intake, upstream end model-data continuous temperature comparison, 2002

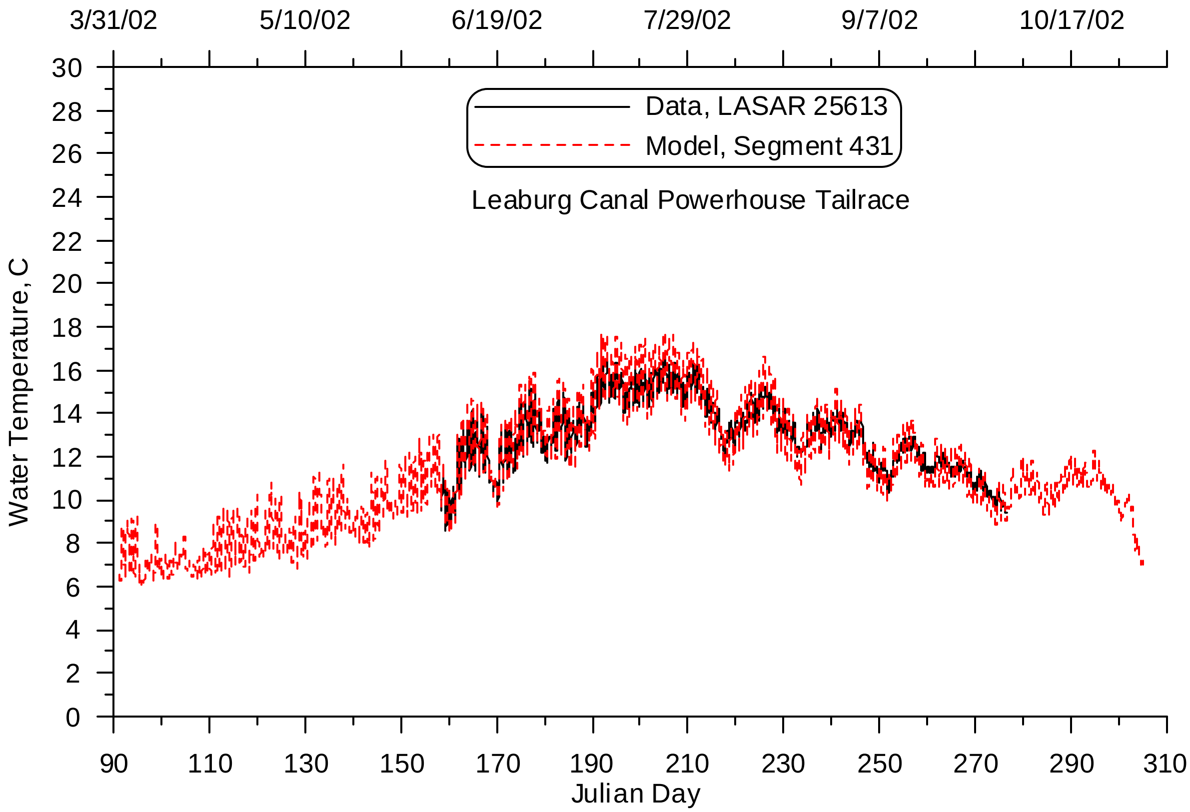

Figure 383: Leaburg Canal Powerhouse Tailrace, downstream end model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

Year 2001

Temperatures on the McKenzie River were calibrated from May to October 2001. Table 59 lists the model-data error statistics for the daily maximum temperature. The table shows absolute mean errors (AME) of less than 1.0 ^{o}C and root mean square error (RMS) of less than 1.2 ^{o}C. Overall the mean error shows there is slight bias on the cooler side of about 0.2 ^{o}C.

Figure 384 to Figure 392 show model-data daily maximum temperature comparisons on the McKenzie River from the upstream boundary down to Bellinger Landing at RM 15.6. The figures show the model is consistently in good agreement with the data with some deviations from site to site but no discernable patterns of disagreement.

Figure 393 and Figure 394 show model-data daily maximum temperature comparisons for the upstream and downstream ends of the Leaburg Canal. Both figures show good model-data agreement over the simulation period with some deviations apart near the end of the simulation.

Table 59: McKenzie River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14159500	60.39	4	146	0.20	0.21	0.27
LASAR 26770	50.99	65	139	-0.08	0.34	0.44
USGS 14162500	44.56	108	148	-0.29	0.45	0.54
LASAR 28504	40.74	132	No data			
LASAR 25610	35.72	167	119	-0.10	0.37	0.45
LASAR 25612	30.38	203	119	0.57	0.71	0.83
LASAR 26758	28.45	215	99	-0.16	0.48	0.56
USGS 14163900	24.97	240	70	-0.56	0.72	0.85
LASAR 25614	17.90	285	119	0.30	0.61	0.74
LASAR 26757	15.61	299	101	-0.09	0.59	0.73
LASAR 29645	10.40	333	No data			
LASAR 10376	3.38	378	No data			
LASAR 25611	35.78	402	119	-0.10	0.35	0.43
LASAR 25613	30.27	431	119	0.07	0.37	0.48

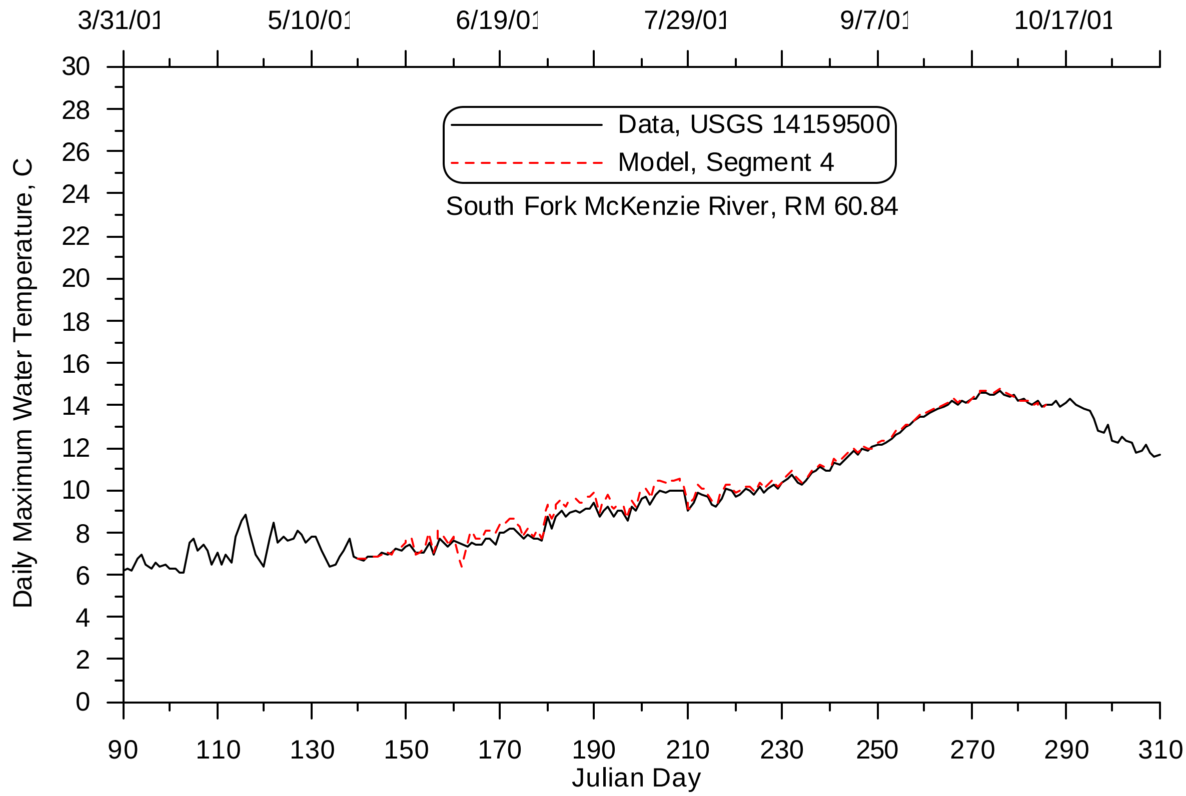

Figure 384: South Fork McKenzie River below Cougar Dam model-data daily maximum temperature comparison, 2001

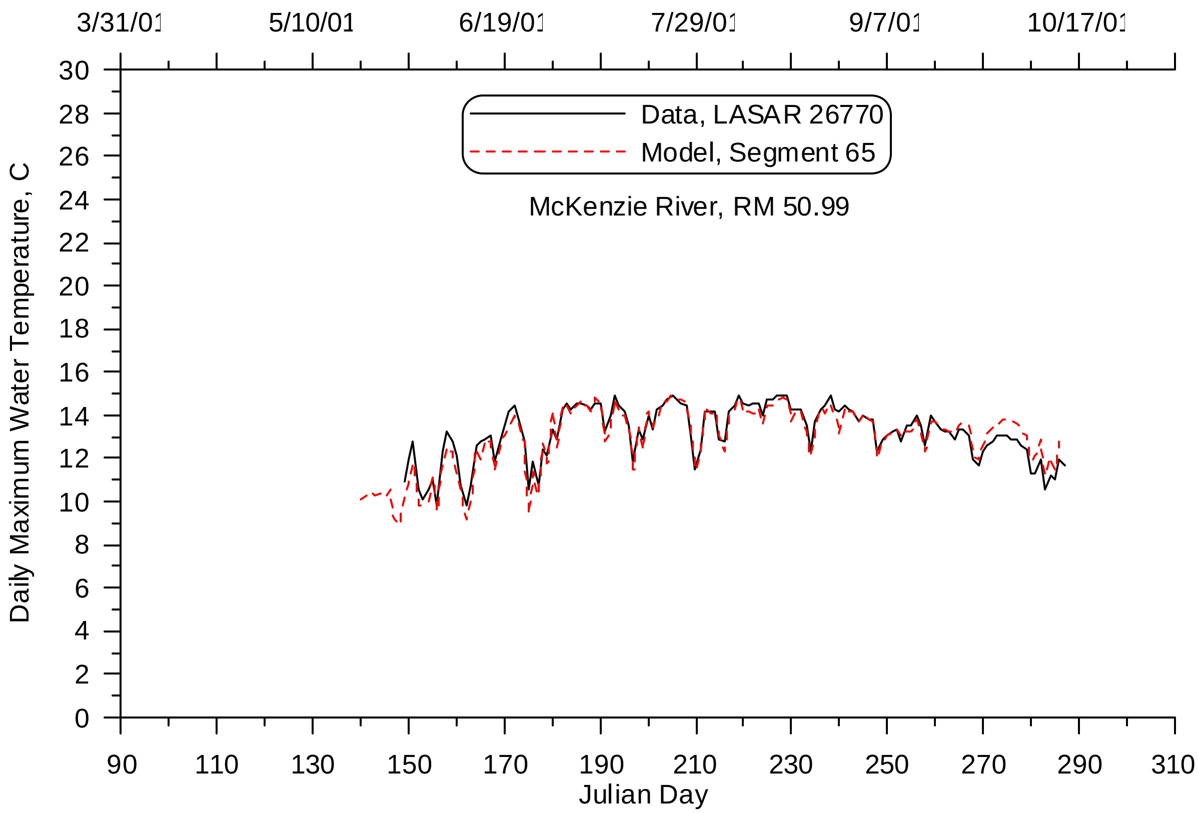

Figure 385: McKenzie River below Cougar River model-data daily maximum temperature comparison, 2001

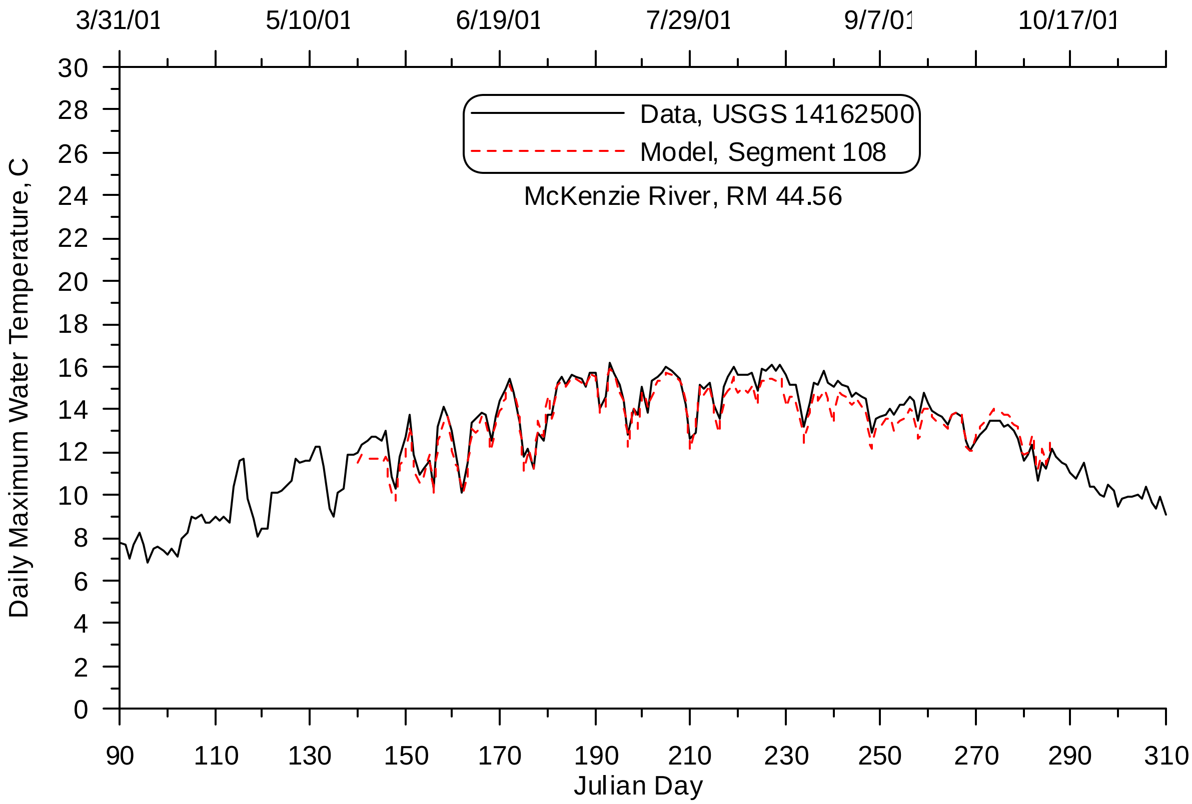

Figure 386: McKenzie River near Vida model-data daily maximum temperature comparison, 2001

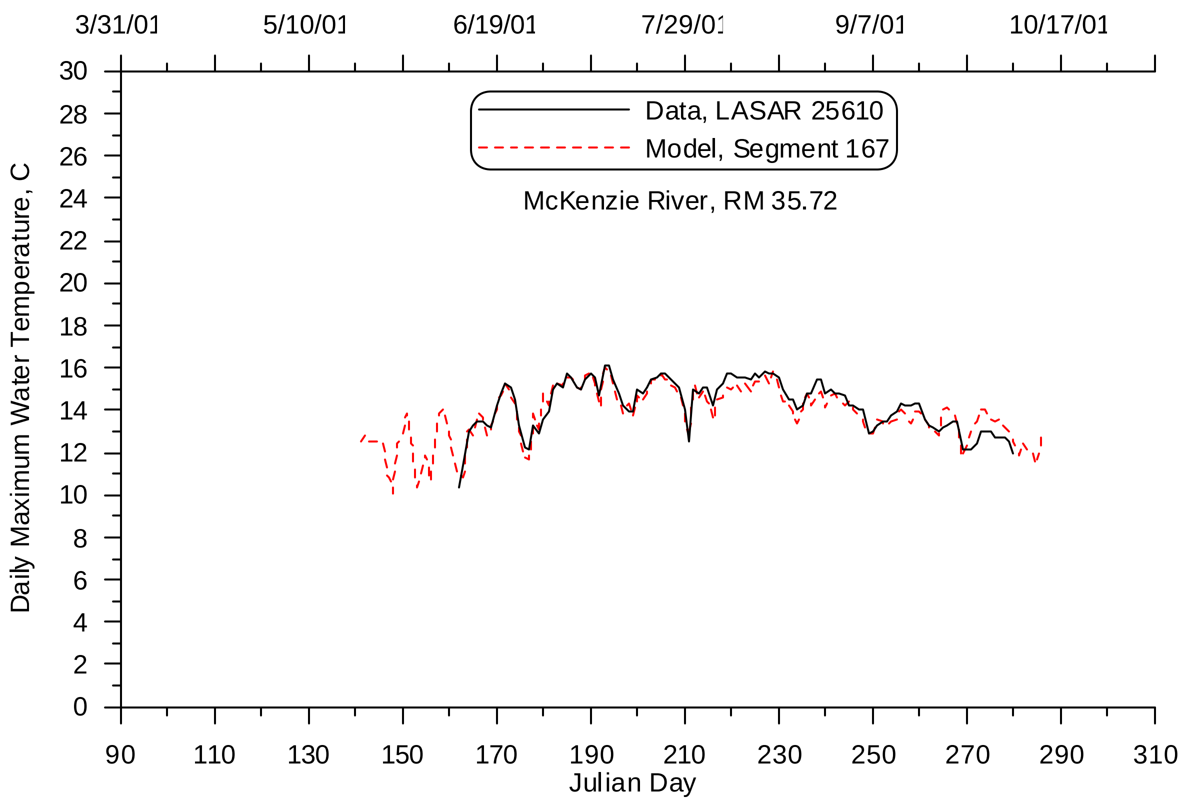

Figure 387: McKenzie River below Leaburg Dam model-data daily maximum temperature comparison, 2001

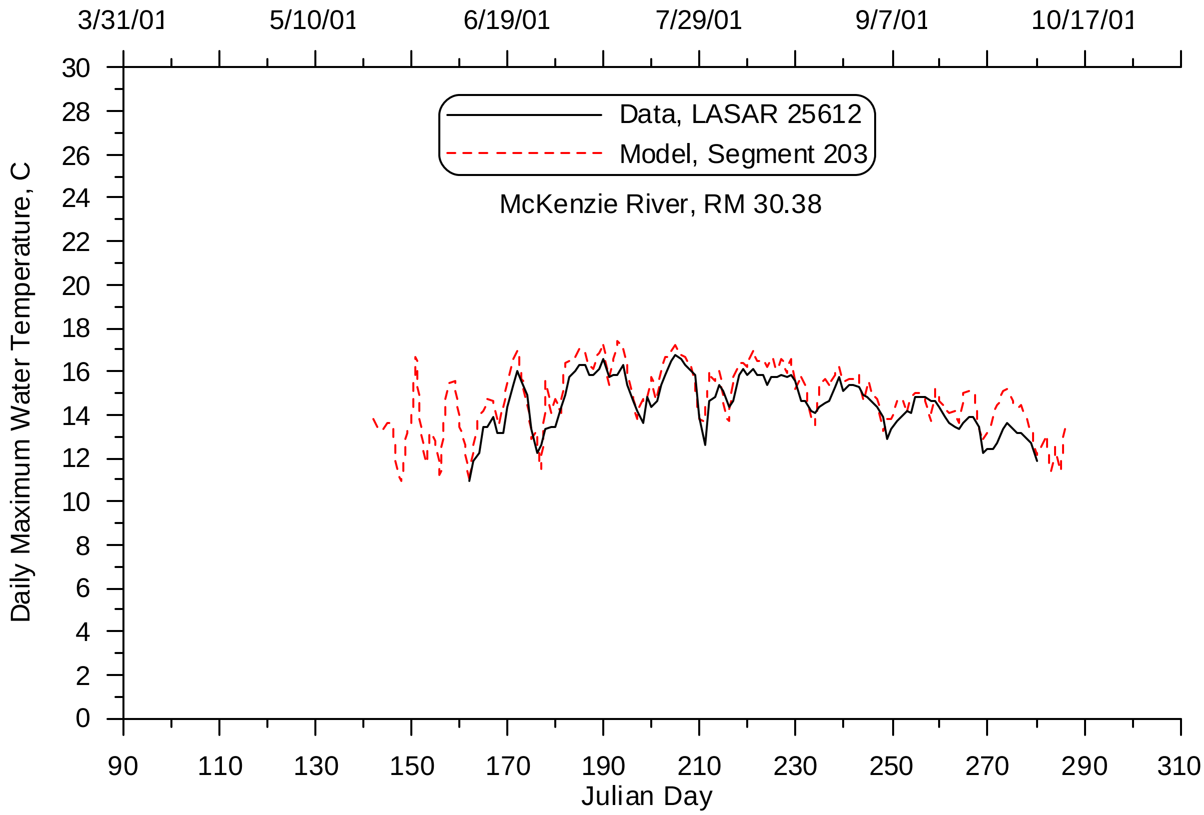

Figure 388: McKenzie River above the Leaburg tailrace model-data daily maximum temperature comparison, 2001

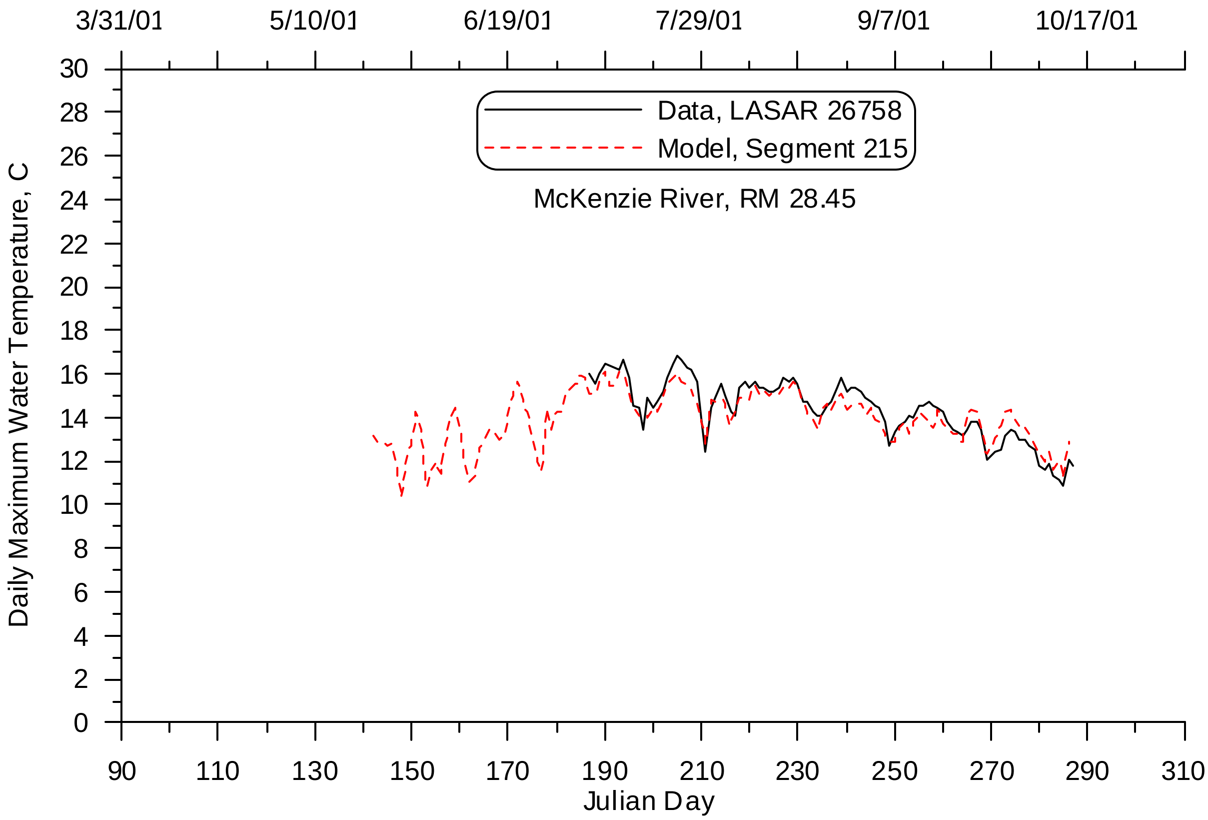

Figure 389: McKenzie River at Deerborn model-data daily maximum temperature comparison, 2001

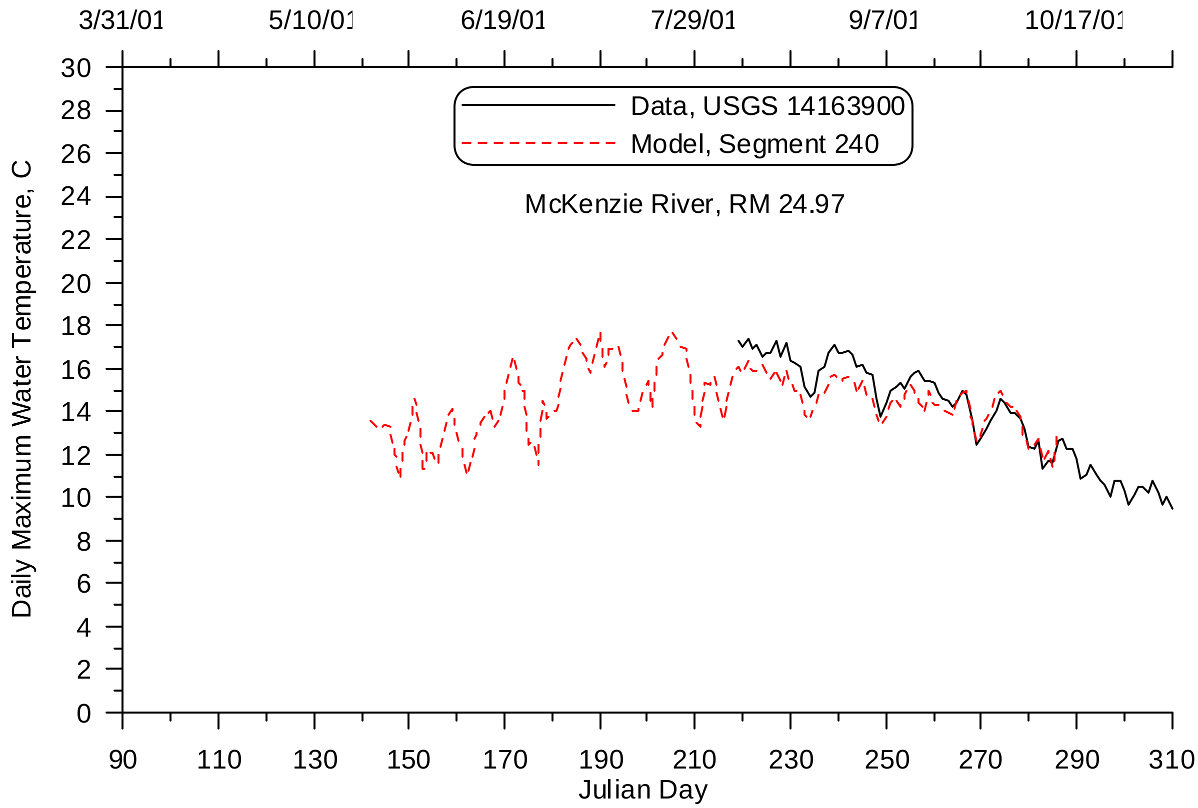

Figure 390: McKenzie River near Walterville model-data daily maximum temperature comparison, 2001

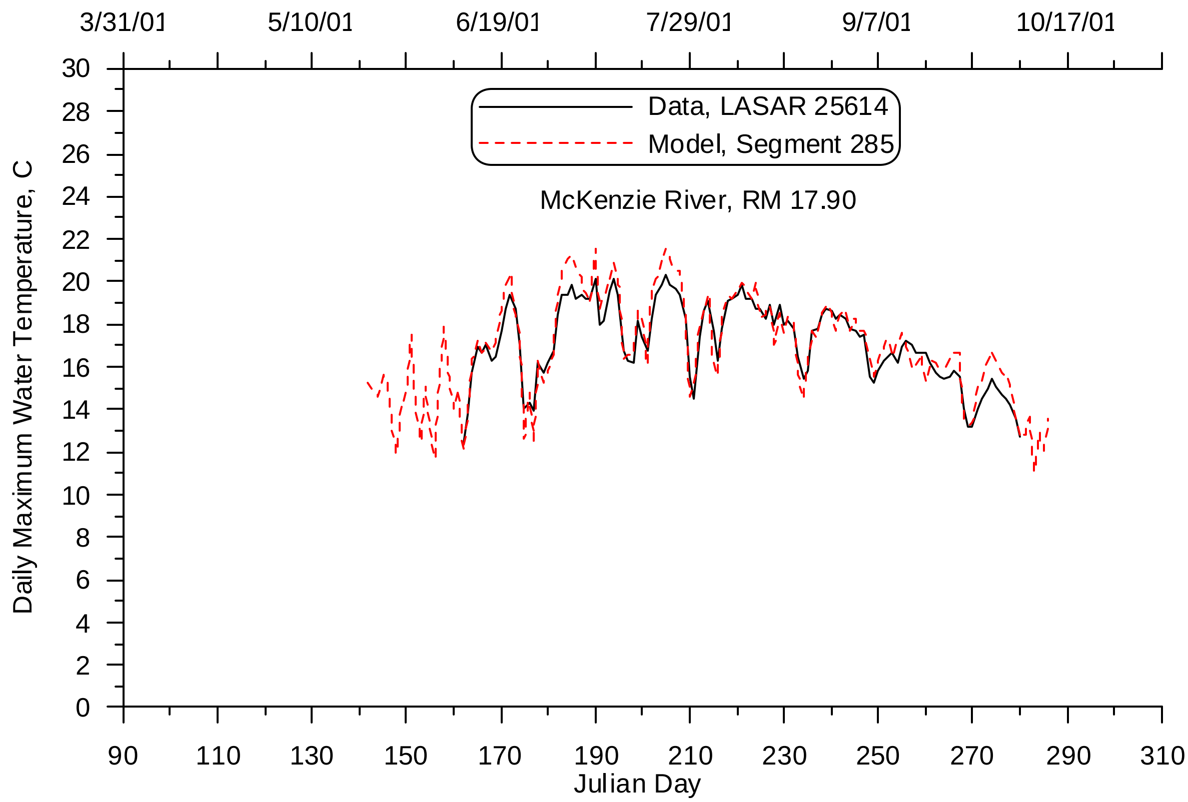

Figure 391: McKenzie River above Walterville Tailrace model-data daily maximum temperature comparison, 2001

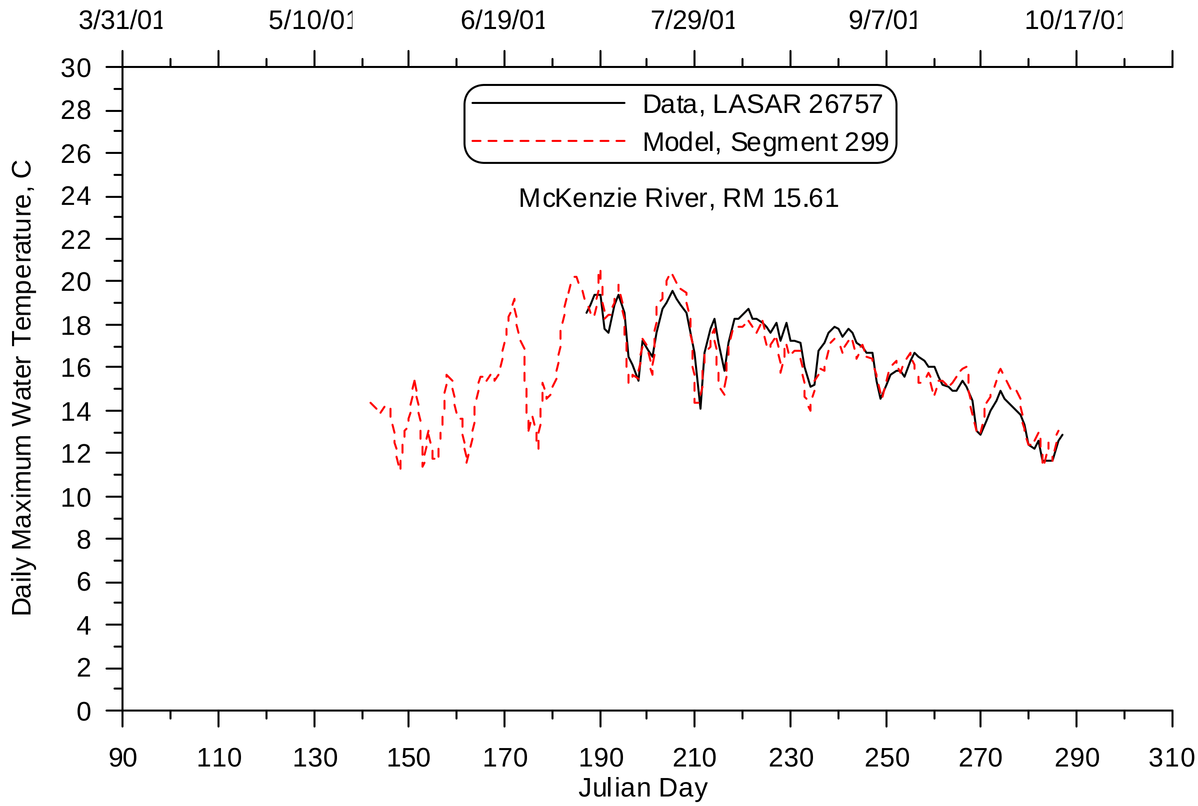

Figure 392: McKenzie River at Bellinger Landing model-data daily maximum temperature comparison, 2001

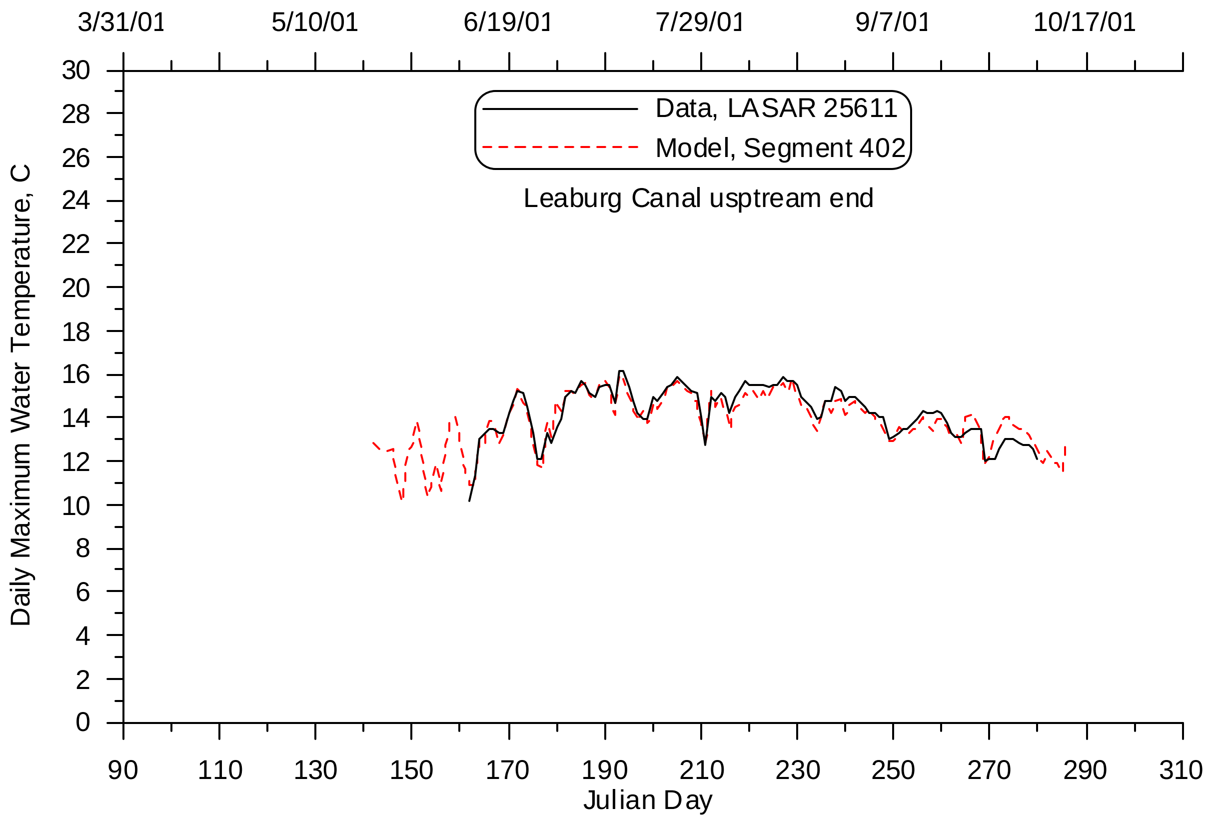

Figure 393: Leaburg Canal Intake, upstream end model-data daily maximum temperature comparison, 2001

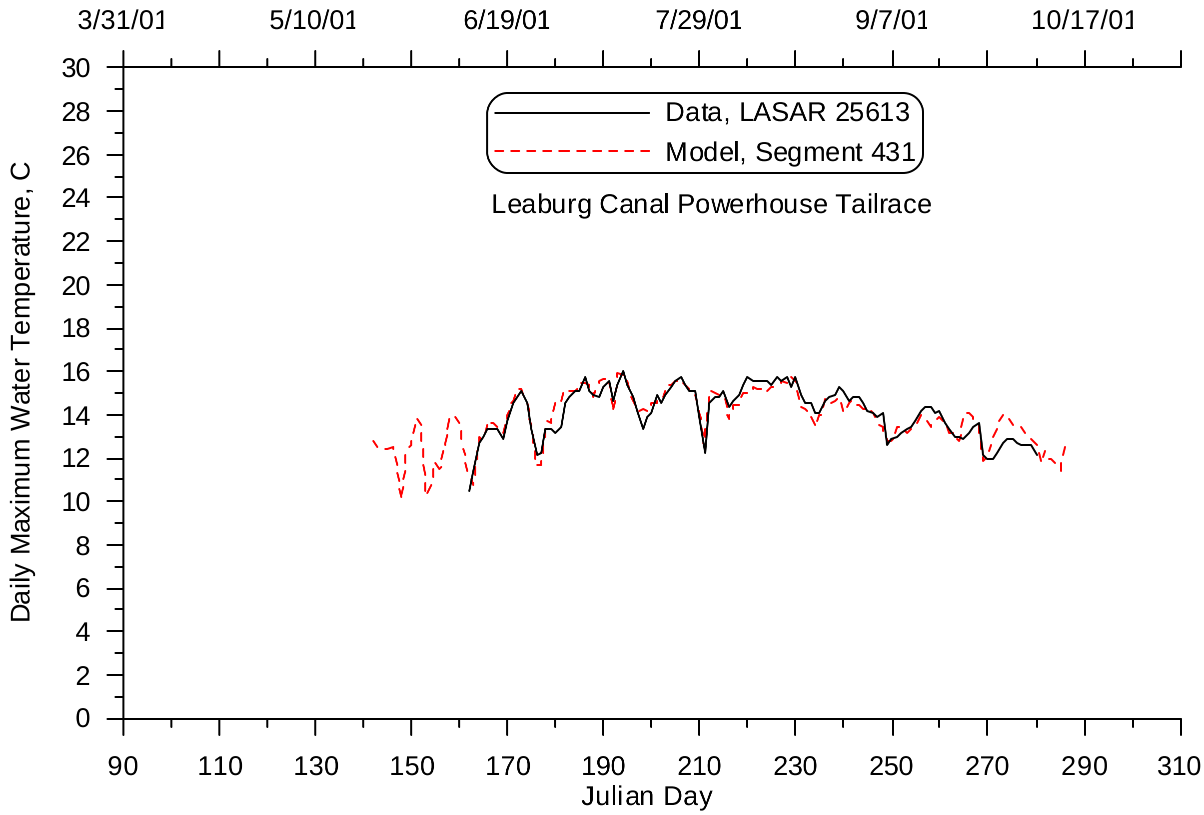

Figure 394: Leaburg Canal Powerhouse Tailrace, downstream end model-data daily maximum temperature comparison, 2001

Year 2002

Temperatures on the McKenzie River were calibrated from April through the end of October. Table 60 lists the model-data error statistics for the daily maximum temperature. The table shows absolute mean errors (AME) of less than 0.8 ^oC and root mean square error (RMS) of less than 0.9 ^oC. Overall the mean error shows there is slight bias on the warmer side of about 0.3 ^oC.

Figure 395 through Figure 404 show model-data daily maximum temperature comparisons on the McKenzie River from the upstream boundary down to Coburg Rd. at RM 3.4. The figures show the model is consistently in good agreement with the data with some deviations from site to site but no discernable patterns of disagreement. There a few sites with agreement near the end of the simulation which may be due to the lack of good boundary condition data at the end of the simulation.

Figure 405 and Figure 406 show model-data daily maximum temperature comparisons for the upstream and downstream ends of the Leaburg Canal. Both figures show relatively good model-data agreement over the simulation period with the model results showing slightly warmer conditions from the middle to late summer.

Table 60: McKenzie River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, °C	AME, °C	RMS, °C
USGS 14159500	60.39	4	10271	0.23	0.23	0.30
LASAR 26770	50.99	65	5856	0.36	0.41	0.50
USGS 14162500	44.56	108	10270	0.41	0.46	0.55
LASAR 28504	40.74	132	3385	0.59	0.61	0.70
LASAR 25610	35.72	167	5668	0.68	0.69	0.78
LASAR 25612	30.38	203	No data			
LASAR 26758	28.45	215	5666	0.23	0.40	0.51
USGS 14163900	24.97	240	10270	0.10	0.41	0.49
LASAR 25614	17.90	285	No data			
LASAR 26757	15.61	299	4870	0.09	0.45	0.63
LASAR 29645	10.40	333	5857	0.23	0.51	0.62
LASAR 10376	3.38	378	5715	0.46	0.59	0.70
LASAR 25611	35.78	402	5669	0.67	0.68	0.77
LASAR 25613	30.27	431	5667	0.72	0.74	0.85

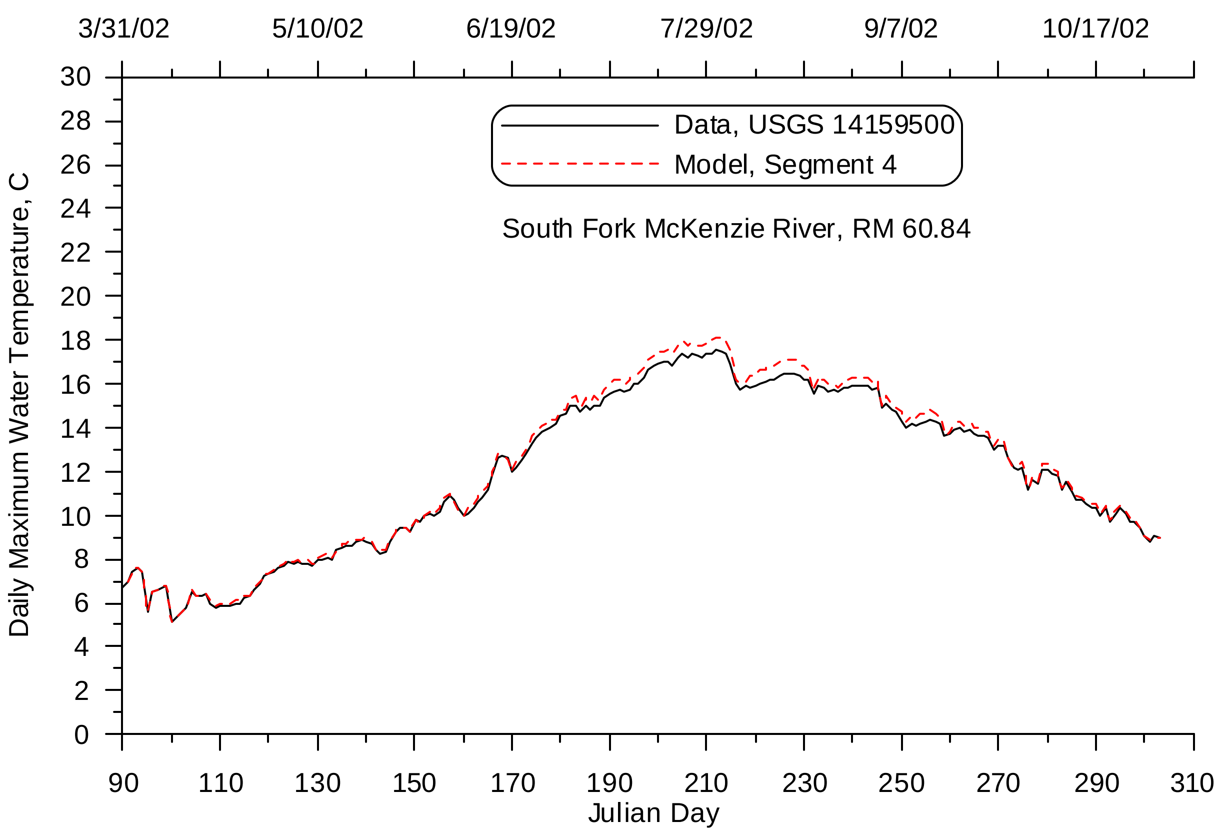

Figure 395: South Fork McKenzie below Cougar Dam model-data daily maximum temperature comparison, 2002

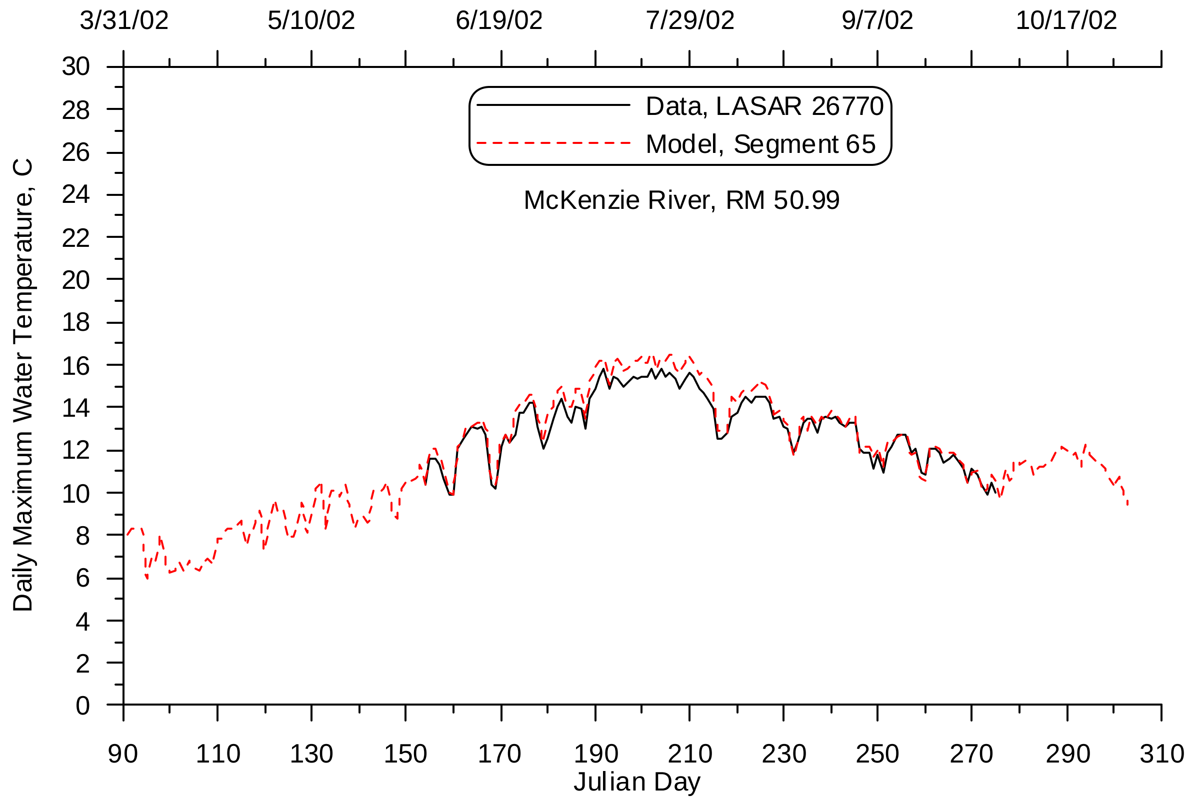

Figure 396: McKenzie River below Cougar River model-data daily maximum temperature comparison, 2002

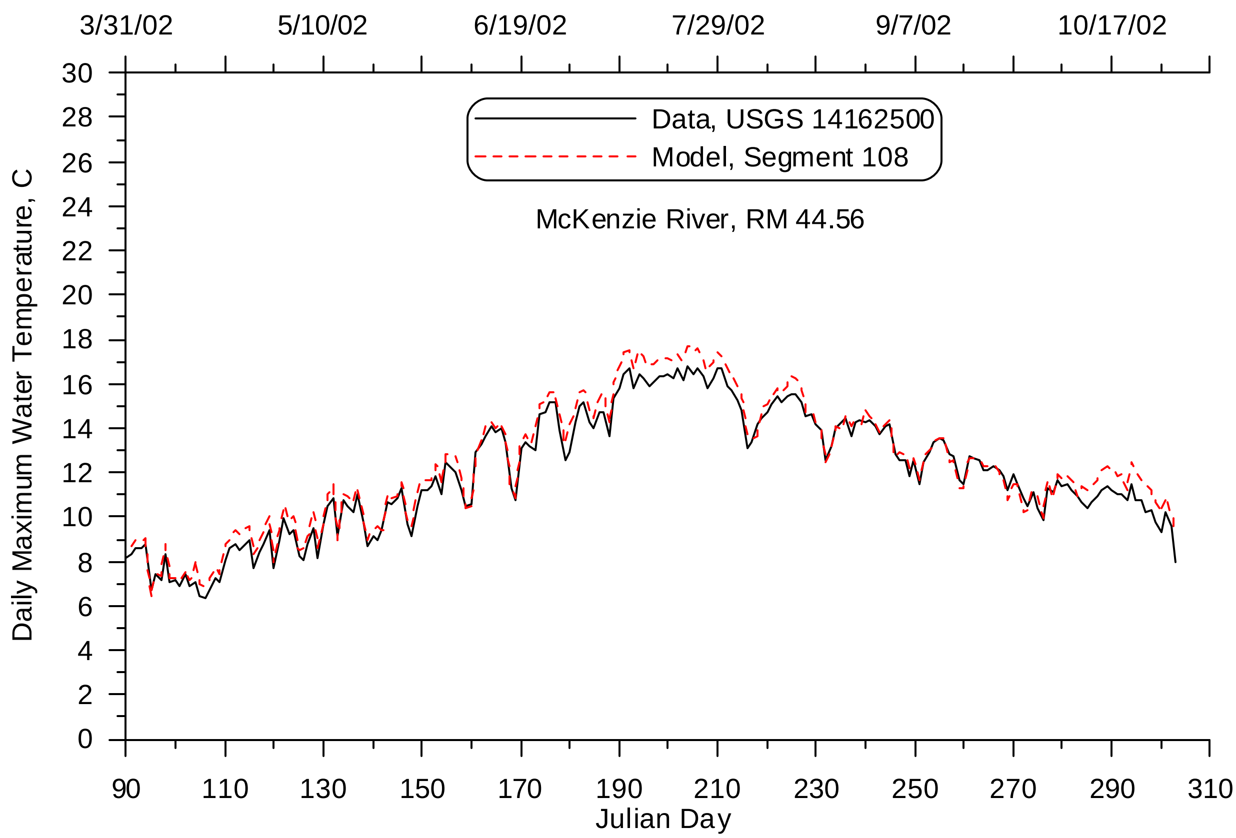

Figure 397: McKenzie River near Vida model-data daily maximum temperature comparison, 2002

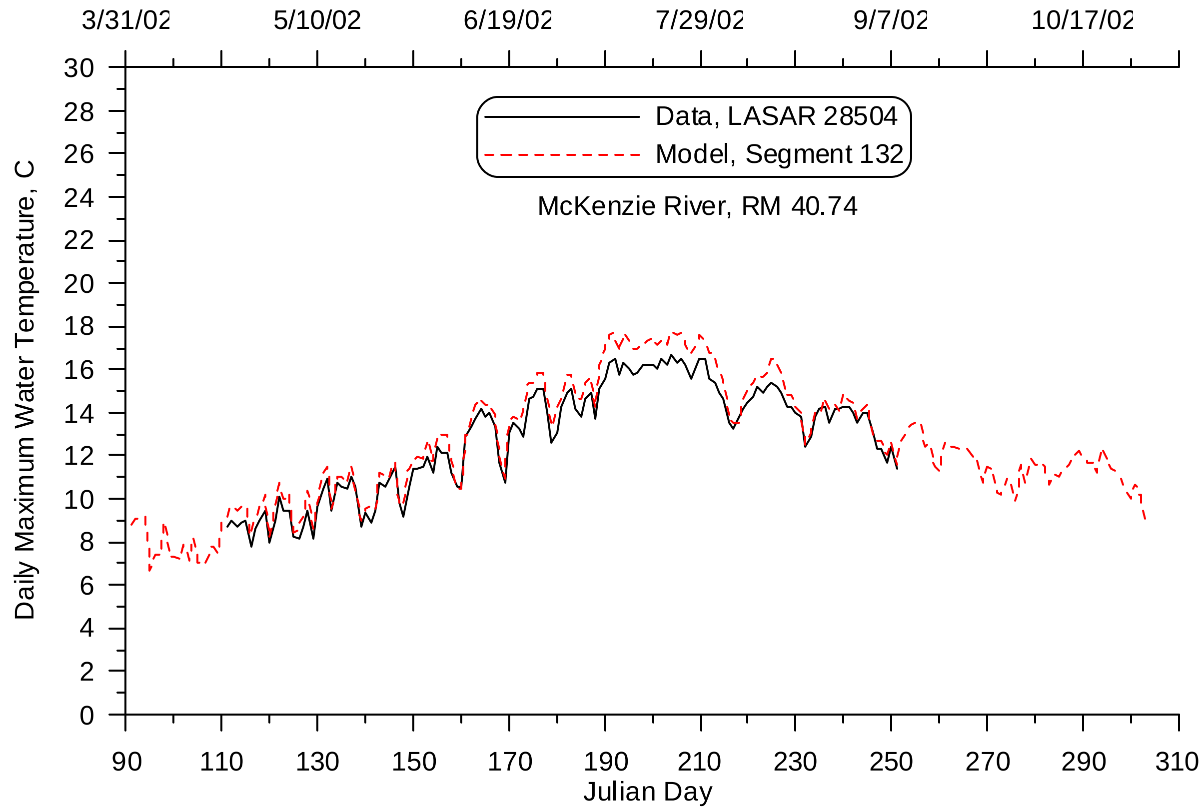

Figure 398: McKenzie River at Helfrich boat ramp model-data daily maximum temperature comparison, 2002

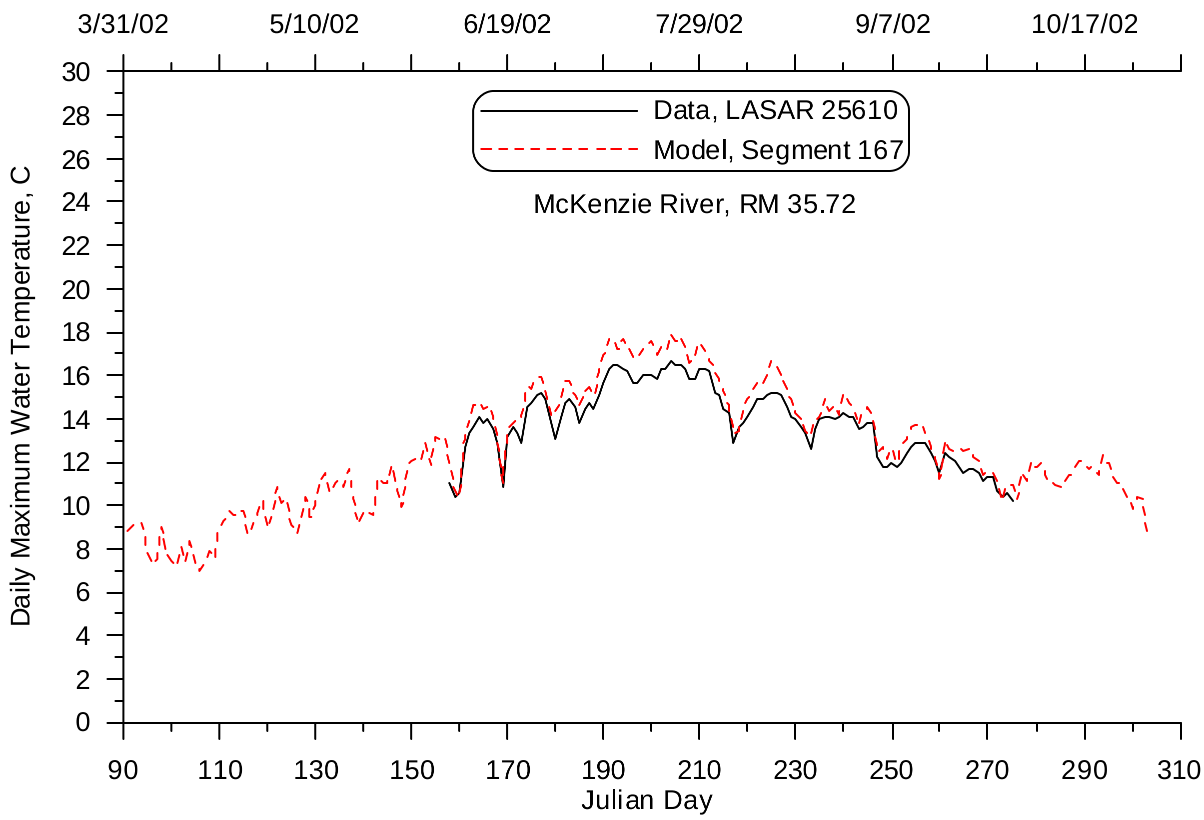

Figure 399: McKenzie River below Leaburg Dam model-data daily maximum temperature comparison, 2002

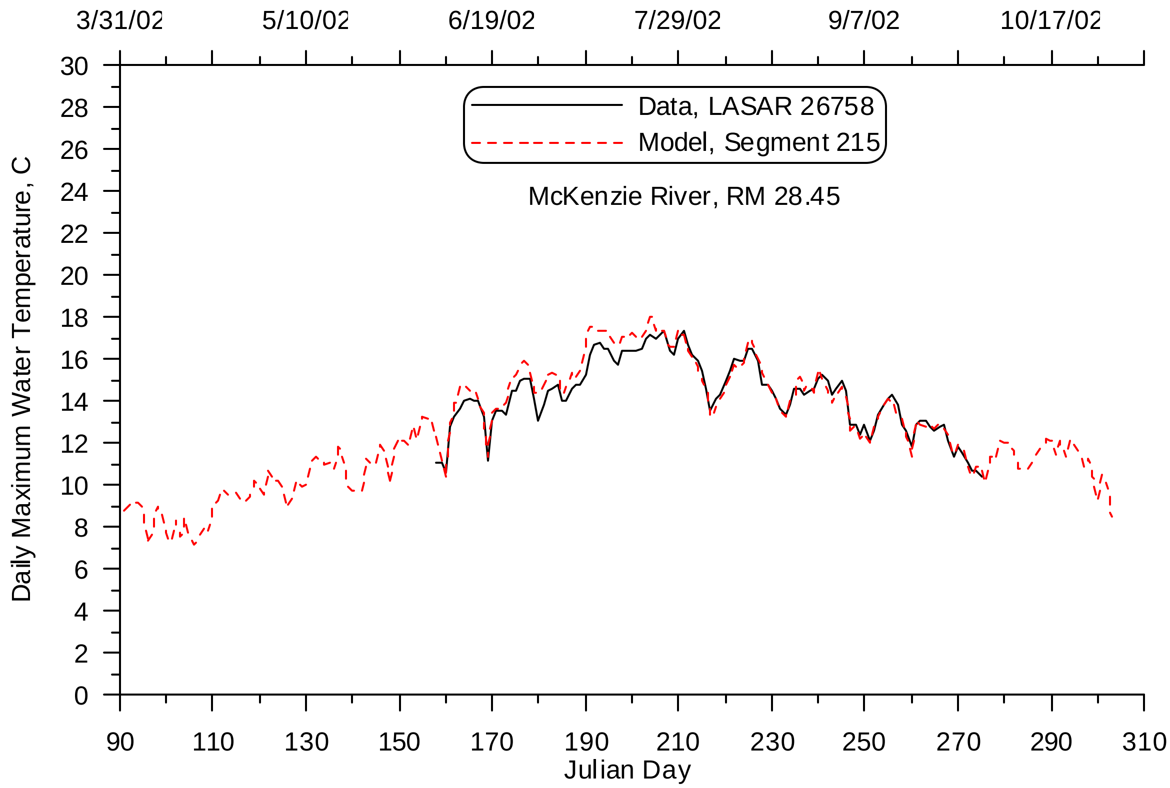

Figure 400: McKenzie River at Deerborn model-data daily maximum temperature comparison, 2002

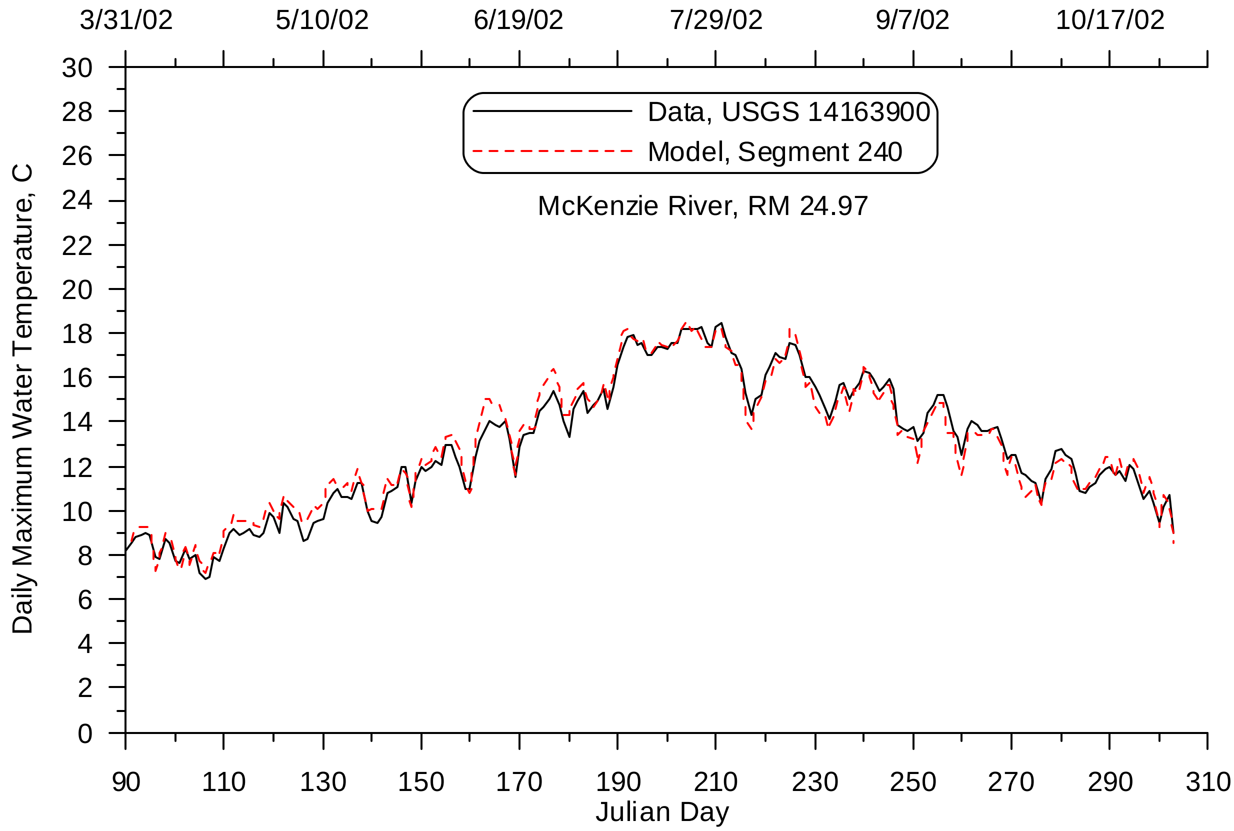

Figure 401: McKenzie River near Walterville model-data daily maximum temperature comparison, 2002

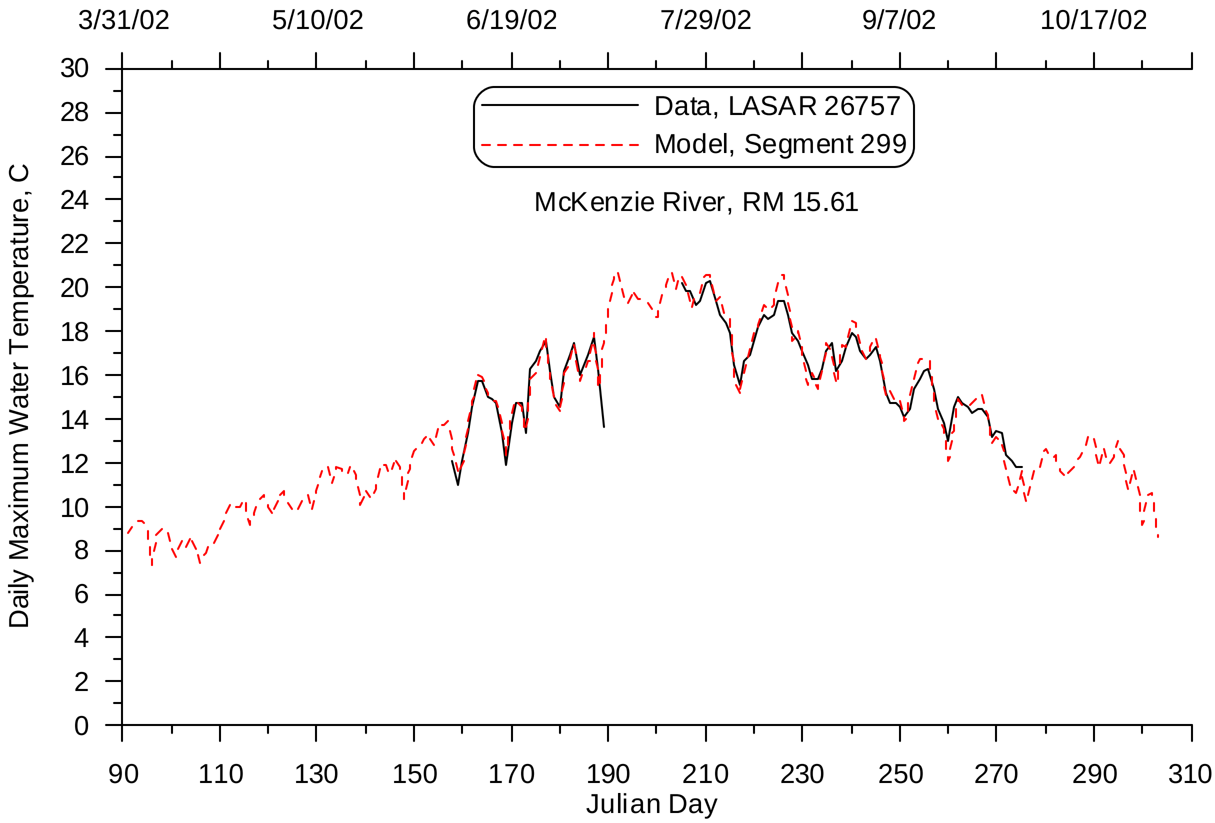

Figure 402: McKenzie River at Bellinger Landing model-data daily maximum temperature comparison, 2002

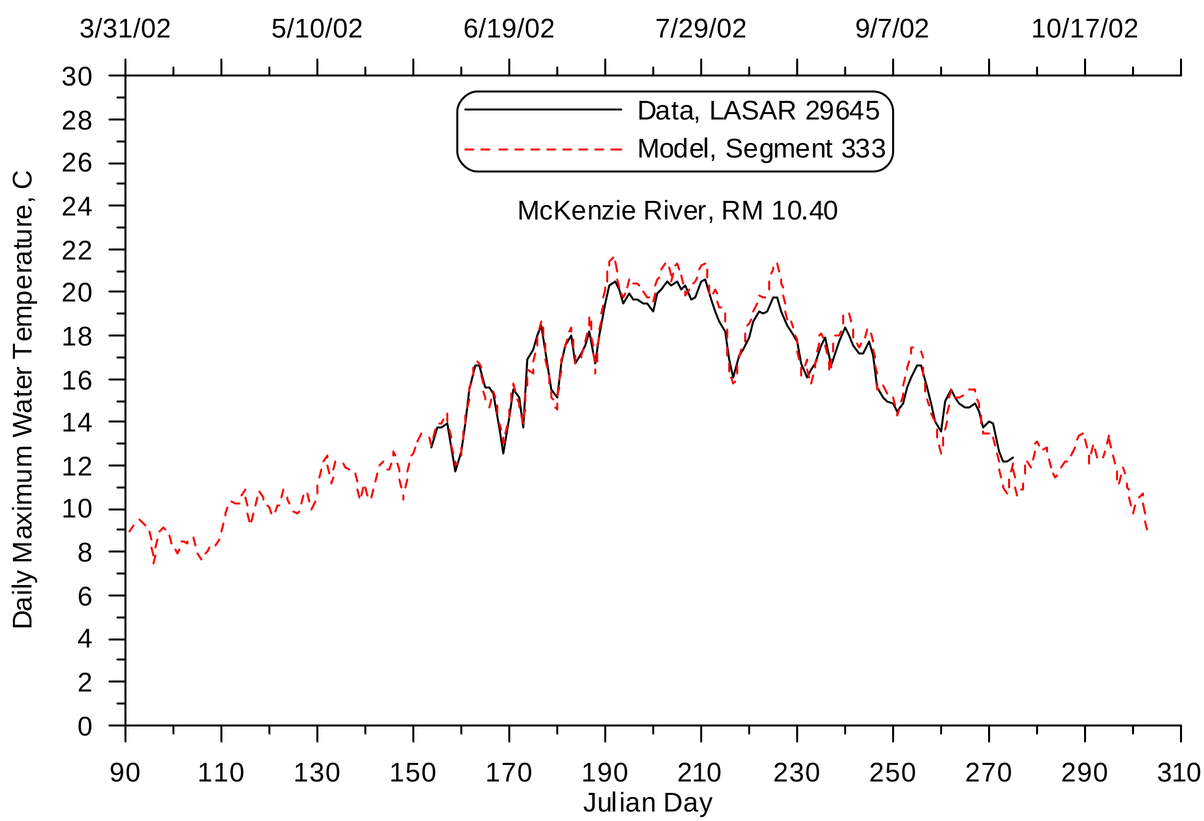

Figure 403: McKenzie River above Mohawk River model-data daily maximum temperature comparison, 2002

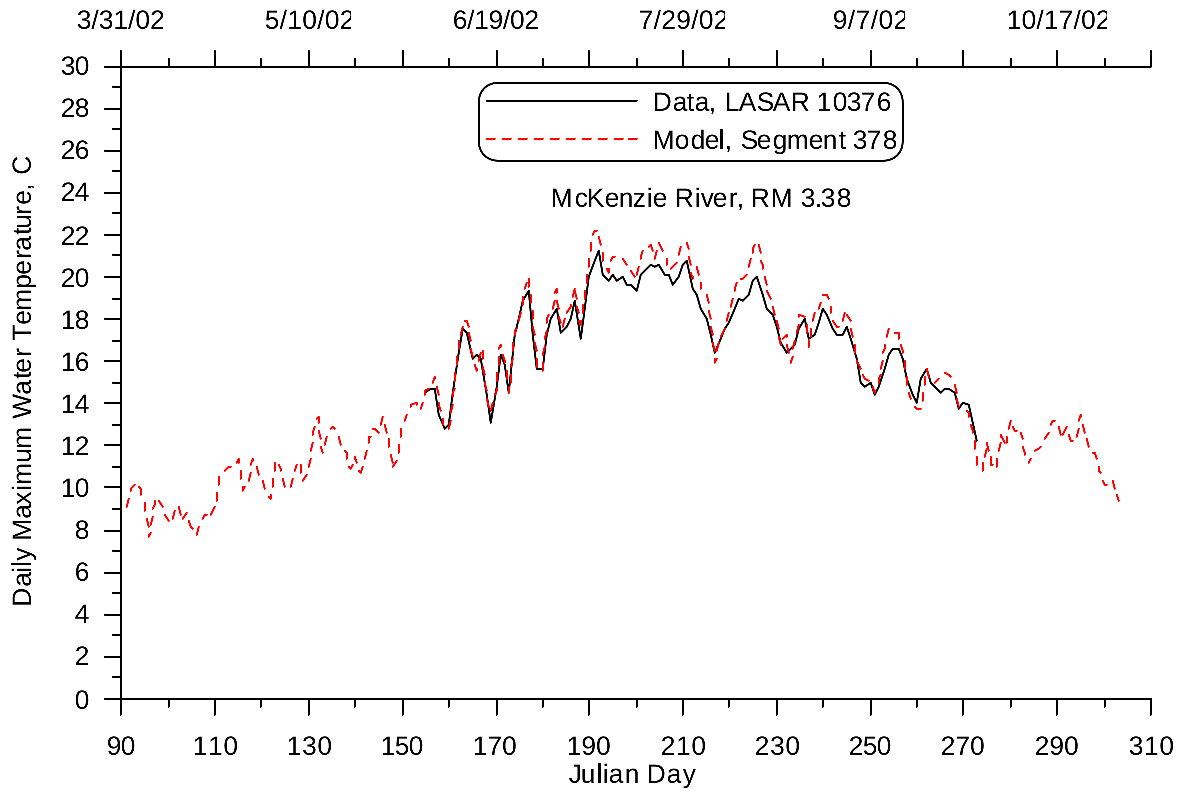

Figure 404: McKenzie River at Coburg Rd model-data daily maximum temperature comparison, 2002

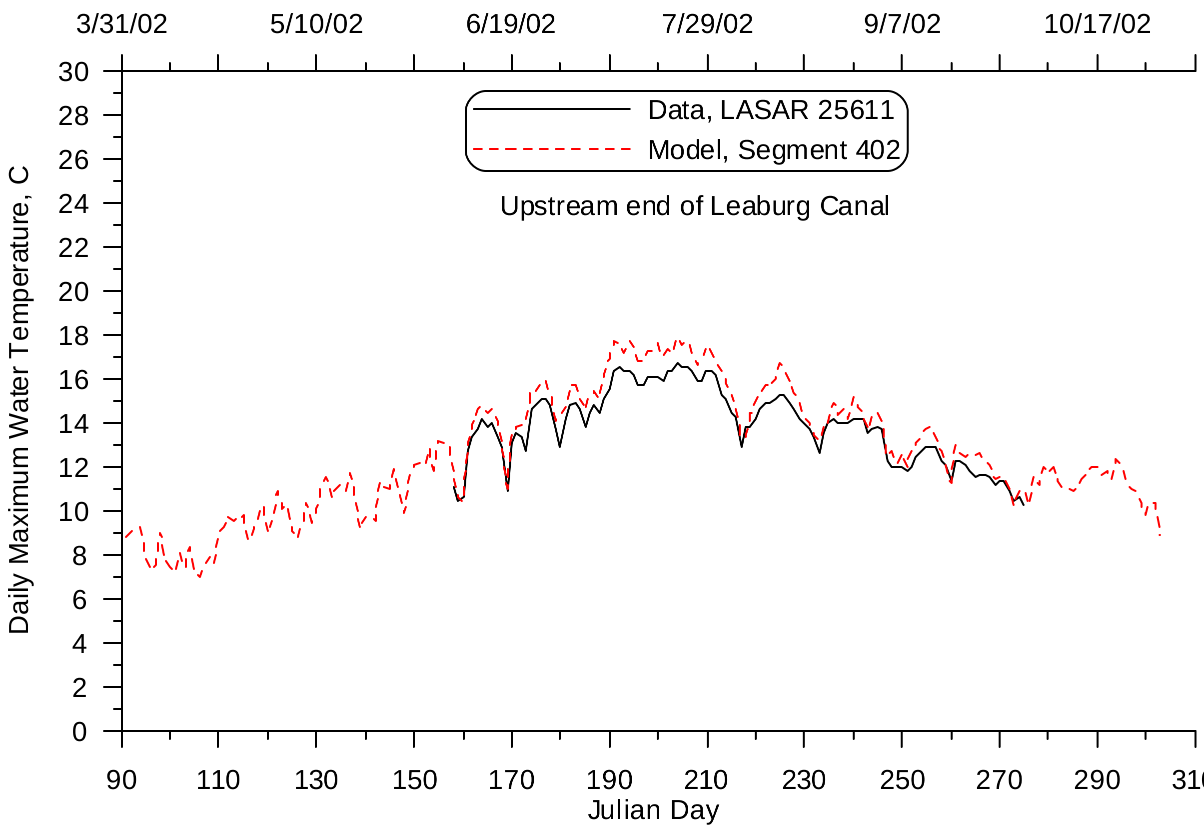

Figure 405: Leaburg Canal Intake, upstream end model-data daily maximum temperature comparison, 2002

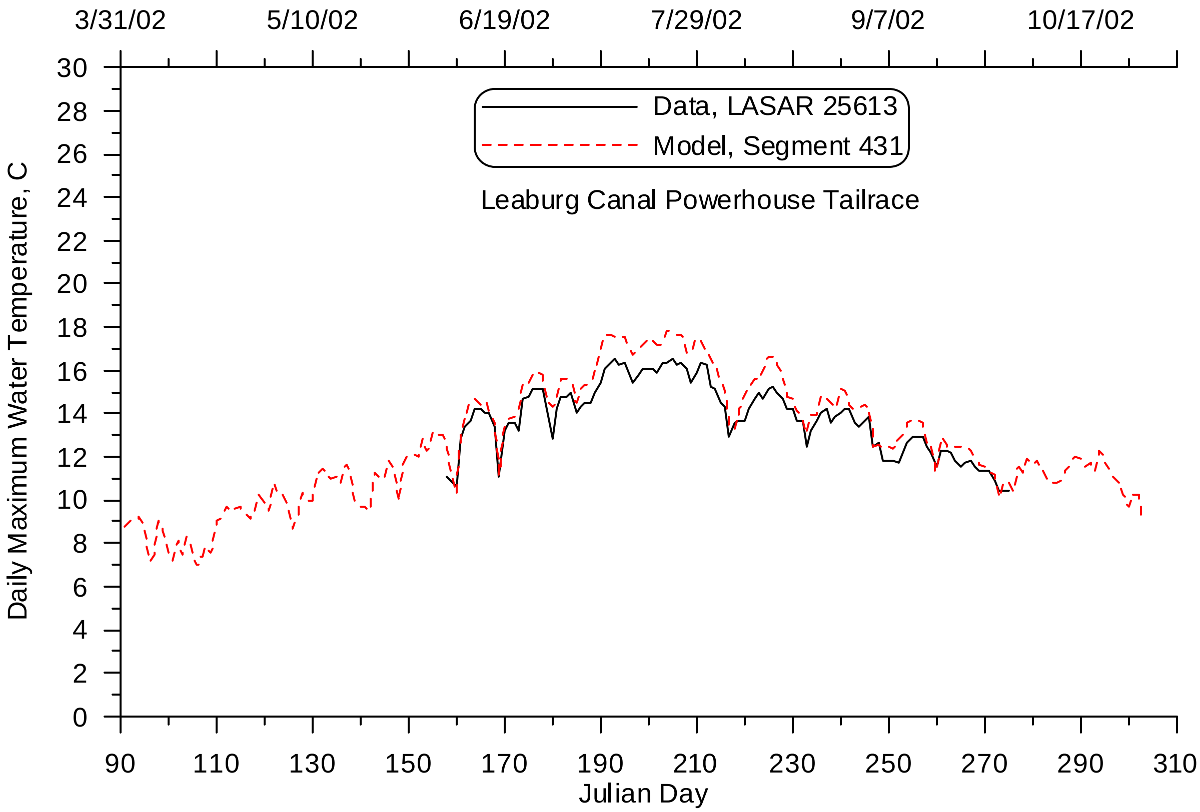

Figure 406: Leaburg Canal Powerhouse Tailrace, downstream end model-data daily maximum temperature comparison, 2002

Coast Fork / Middle Fork Willamette River

Introduction

The Coast Fork and Middle Fork Willamette River model calibration was performed in a series of steps. Hydrodynamics, or water level and flow rates, were calibrated first, followed channel widths and time of travel studies, and then temperature. Figure 407 shows the model domain which includes the Coast Fork Willamette River and the tributary Row River and the Middle Fork Willamette River and a large tributary, Fall Creek. The model calibration period for 2001 and 2002 was from April 1 to October 31 but there was a lack of good boundary condition data in 2001 and less so in 2002.

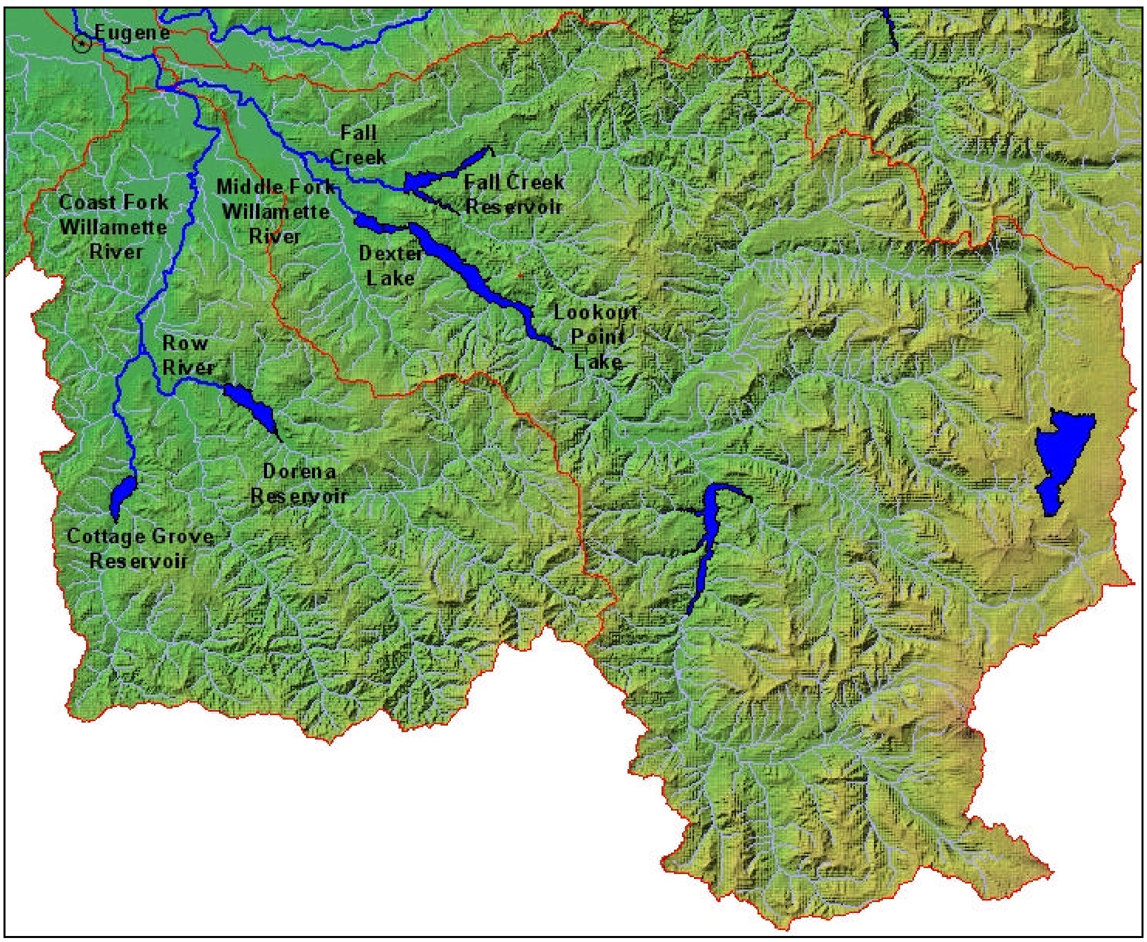

Figure 407: Coast Fork and Middle Fork Willamette River model region

Hydrodynamics

The hydrodynamics were calibrated using water level and flow data. The calibration parameters used were Manning's friction factor, adjustments to the channel slope, and adjustments to channel widths since there was limited bathymetric data for the rivers.

Flow and Water Surface Elevation

The Coast Fork and Middle Fork Willamette Rivers each have two gage stations with continuous flow and water surface elevation data for calibrating the model. Row River and Fall Creek each have one gage station with flow and water level data. Figure 408 shows a map of the basins with the gage site locations and Table 61 shows a list of the gage sites with RM and corresponding model segment.

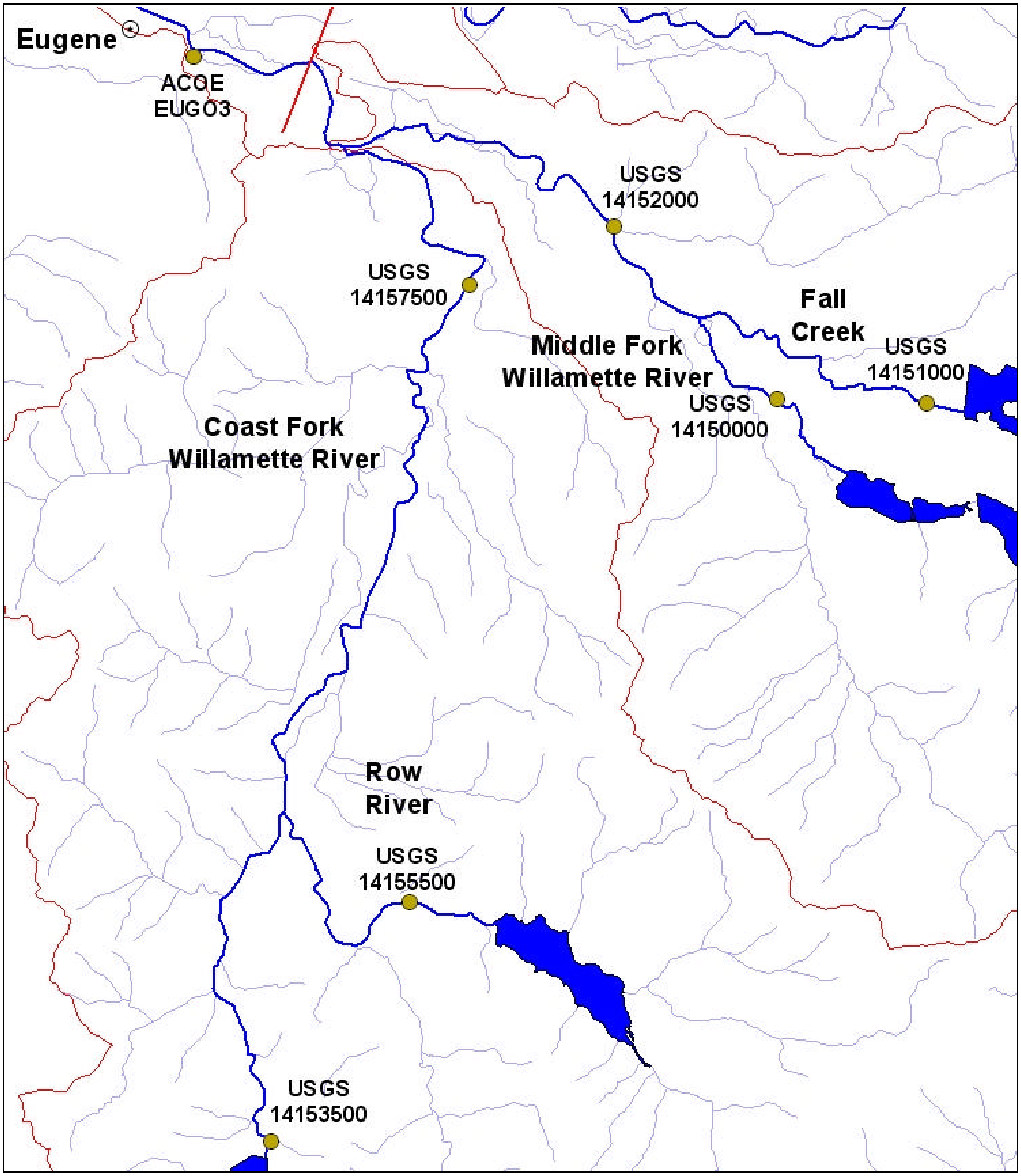

Figure 408: USGS Gage Stations on Coast Fork and Middle Fork Willamette River

Table 61: Coast Fork and Middle Fork Willamette River hydrodynamics calibration sites

Site ID	Site Description	RM	Model Segment	Data 2001 & 2002
USGS 14153500	Coast Fork below Cottage Grove Dam (u/s Row River)	28.69	4	Q & WL
USGS 14157500	Coast Fork Willamette River near Goshen (d/s Row River)	5.72	153	Q & WL
USGS 14155500	Row River near Cottage Grove	5.51	206	Q & WL
USGS 14150000	Middle Fork Willamette River near Dexter (u/s Fall Creek)	13.95	264	Q & WL
USGS 14152000	Middle Fork Willamette River at Jasper (d/s Fall Creek)	8.15	303	Q & WL
USGS 14151000	Fall Creek below Winberry Creek near Fall Creek	6.29	363	Q & WL
ACOE EUGO3	Willamette River at Eugene	185.08	416	Q*
Q = Flow and WL = Water Level, * (downstream of model domain)				

Year 2001

The hydrodynamics calibration was conducted from April to October in 2001 for both flow and water level. Table 62 lists the model-data error statistics for both flow and water level. The error statistics show good model-data agreement throughout the system for both flow and water level with the furthest downstream site (ACOE EUGO3) having the largest model-data error. The absolute mean error (AME) for flow ranged from 0.01 to 1.1 m^3/s and the root mean square error (RMS) for flow ranged from 0.05 to 2.2 m^3/s. Water level model-data error statistics ranged from 0.03 to 0.19 for AME and 0.04 to 0.21 for RMS error.

Figure 409 and Figure 410 show model-data comparison plots for the Coast Fork Willamette River below Cottage Grove Dam for flow and water level, respectively. Since this gage station is only two segments downstream from the upstream boundary condition the model flow results are expected to be close to the data. The vertical resolution of the model grid is 1 meter resulting in instances where the closest the model-data comparisons that can be achieved will fall with one model layer. In some cases the water level stays in the same model layers for most of the simulation with deviations for the lowest and highest flows. Figure 410 shows there is relatively close model-data agreement for the water level except when there is a high flow events.

Figure 411 and Figure 412 show model-data comparison plots for the Coast Fork Willamette River near Goshen (RM 5.7) for flow and water level, respectively. The gage station is downstream of where Row River enters the Coast Fork River (RM 20.12). The flow comparison figure shows several small flow spikes in the model results. These spikes are the result of low flows in the system, rapid changes in the flow regime of the model, and lack of detailed bathymetric data for the river channel.

Figure 413 and Figure 414 show model-data comparisons for the Row River for flow and water level, respectively. The upstream boundary condition for Row River is at RM 7.5 and the comparison location in 2 miles downstream at RM 5.5 so the model flow should match closely with the data. The water level results at this gage station also match closely with the data showing a small bias of under predicting water levels over the simulation period.

Figure 415 and Figure 416 show flow and water level results compared with data for the Middle Fork Willamette River near Dexter, OR. This site location is approximately 2.6 miles downstream from the upstream boundary condition so the simulated flows are expected to be close to the data. The water level results at this site show relatively good agreement with the data with the exception of the high flow period in May and June, 2001. Figure 417 and Figure 418 show flow and water level results compared with data for the Middle Fork Willamette River at Jasper (RM 8.2) Fall Creek enters the Middle Fork Willamette River at RM 11.1. Both figures show the flow and water level model results are in good agreement with the data.

Figure 419 and Figure 420 show flow and water level results compared with data for Fall Creek at RM 6.3, which is 0.8 miles downstream from the upstream boundary condition below Fall Creek Reservoir. The flow results are close to the data as expected since it is so close to the upstream boundary condition. The water level result sat this site vary considerably for the range of flows in the river. The model does a decent job trying to simulate water levels close to data but there is some disagreement. This could be due a lack of good bathymetric data for the Fall Creek river channel. Water level variations are still within a meter and the flows simulated are following the data closely.

The furthest downstream location to compare simulated flows with data is near the city of Eugene, OR. The monitoring site is RM 181 and the furthest downstream location of the Coast and Middle Fork model is RM 185.1. Figure 421 compares the simulated flows at RM 185.1 and data from RM 181 and indicates there is good model-data agreement. The close agreement between the model and data indicates the Coast and Middle Fork model is simulating the appropriate quantity of water over time and passing it downstream to the Upper Willamette Model.

Table 62: Coast and Middle Fork Willamette River hydrodynamic calibration model-data error statistics, 2001

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14153500	28.69	4	10174	0.01	0.01	0.05
USGS 14157500	5.72	153	9448	-0.11	0.42	1.21
USGS 14155500	5.51	206	10174	0.00	0.05	0.32
USGS 14150000	13.95	264	10174	-0.01	0.35	0.80
USGS 14152000	8.15	303	10080	0.01	0.58	1.17
USGS 14151000	6.29	363	10174	0.01	0.06	0.25
ACOE EUGO3	185.08	416	10136	0.45	1.10	2.15
Water Level						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14153500	28.69	4	10174	-0.04	0.11	0.14
USGS 14157500	5.72	153	9448	-0.02	0.03	0.05
USGS 14155500	5.51	206	10174	-0.04	0.04	0.04
USGS 14150000	13.95	264	10174	0.06	0.10	0.20
USGS 14152000	8.15	303	10080	0.01	0.03	0.04
USGS 14151000	6.29	363	10174	0.08	0.19	0.21
ACOE EUGO3	185.08	416	Not a valid comparison since the site is downstream of the model domain			

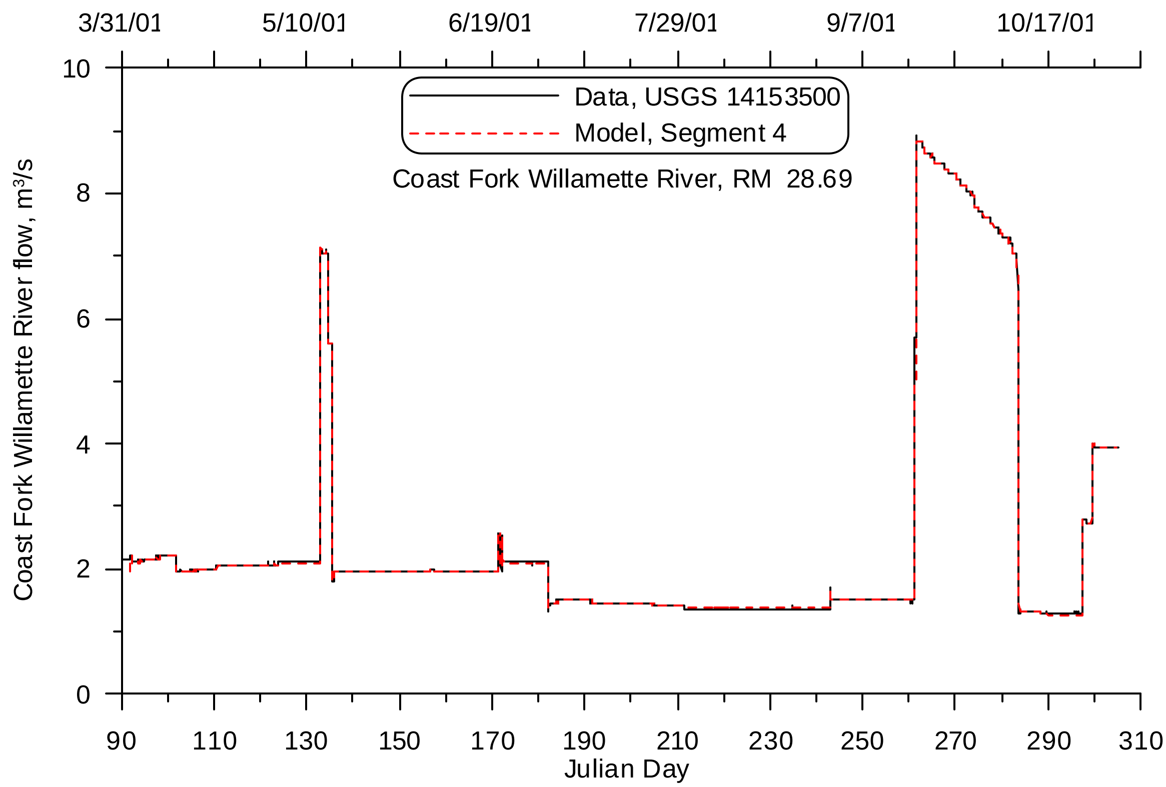

Figure 409: Coast Fork Willamette River below Cottage Grove Dam model-data flow comparison, 2001

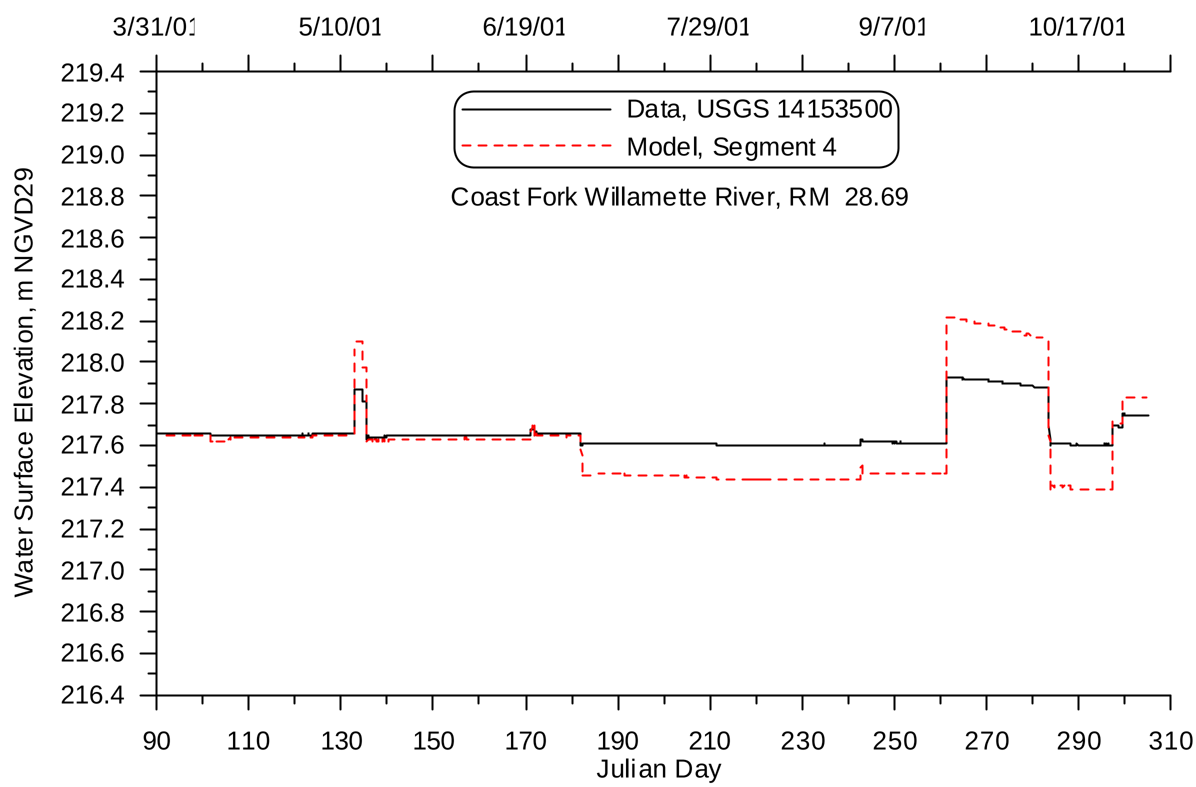

Figure 410: Coast Fork Willamette River below Cottage Grove Dam model-data water level comparison, 2001

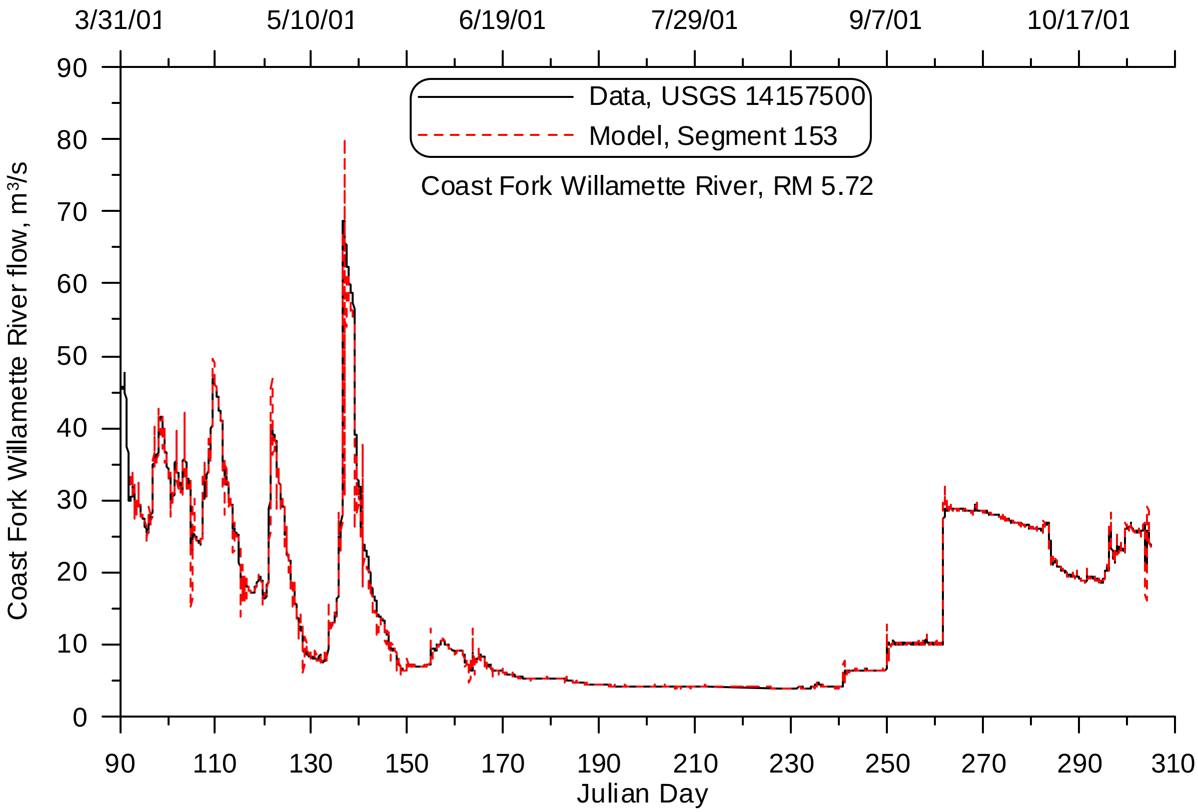

Figure 411: Coast Fork Willamette River near Goshen model-data flow comparison, 2001

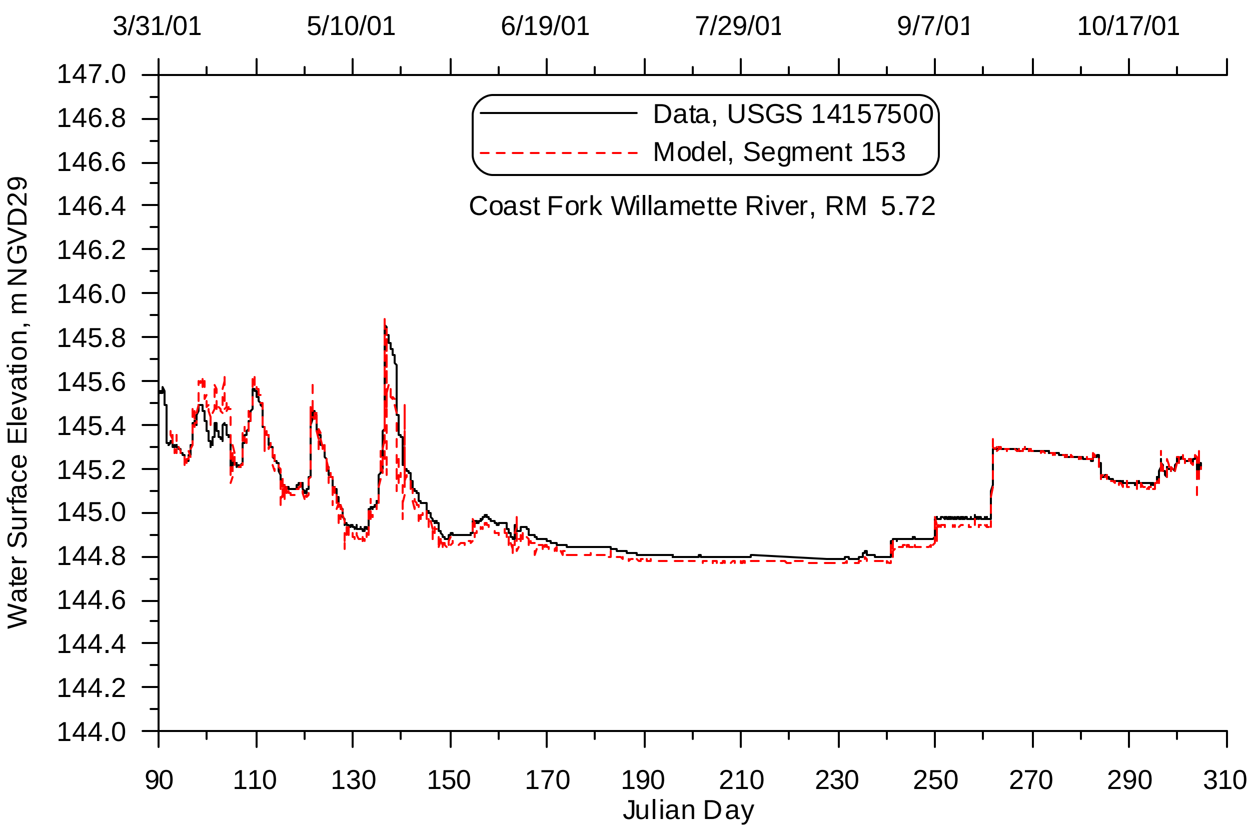

Figure 412: Coast Fork Willamette River near Goshen model-data water level comparison, 2001

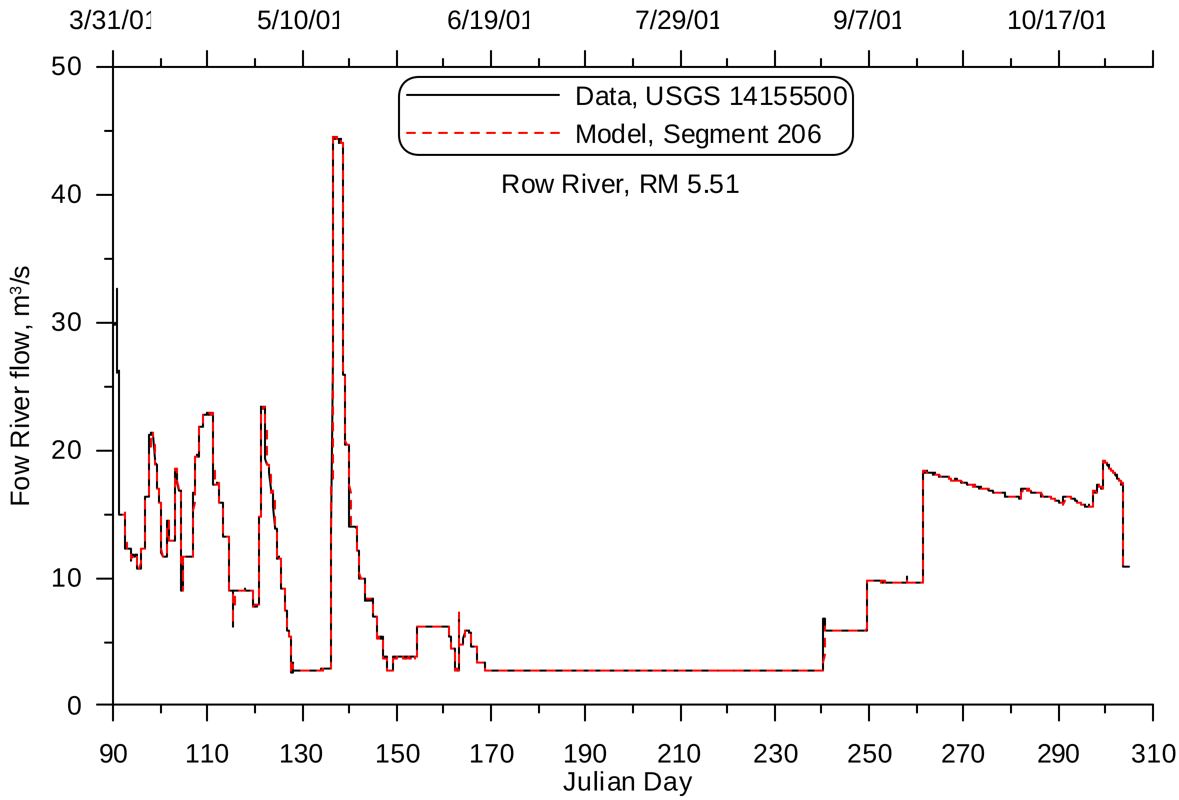

Figure 413: Row River near Cottage Grove model-data flow comparison, 2001

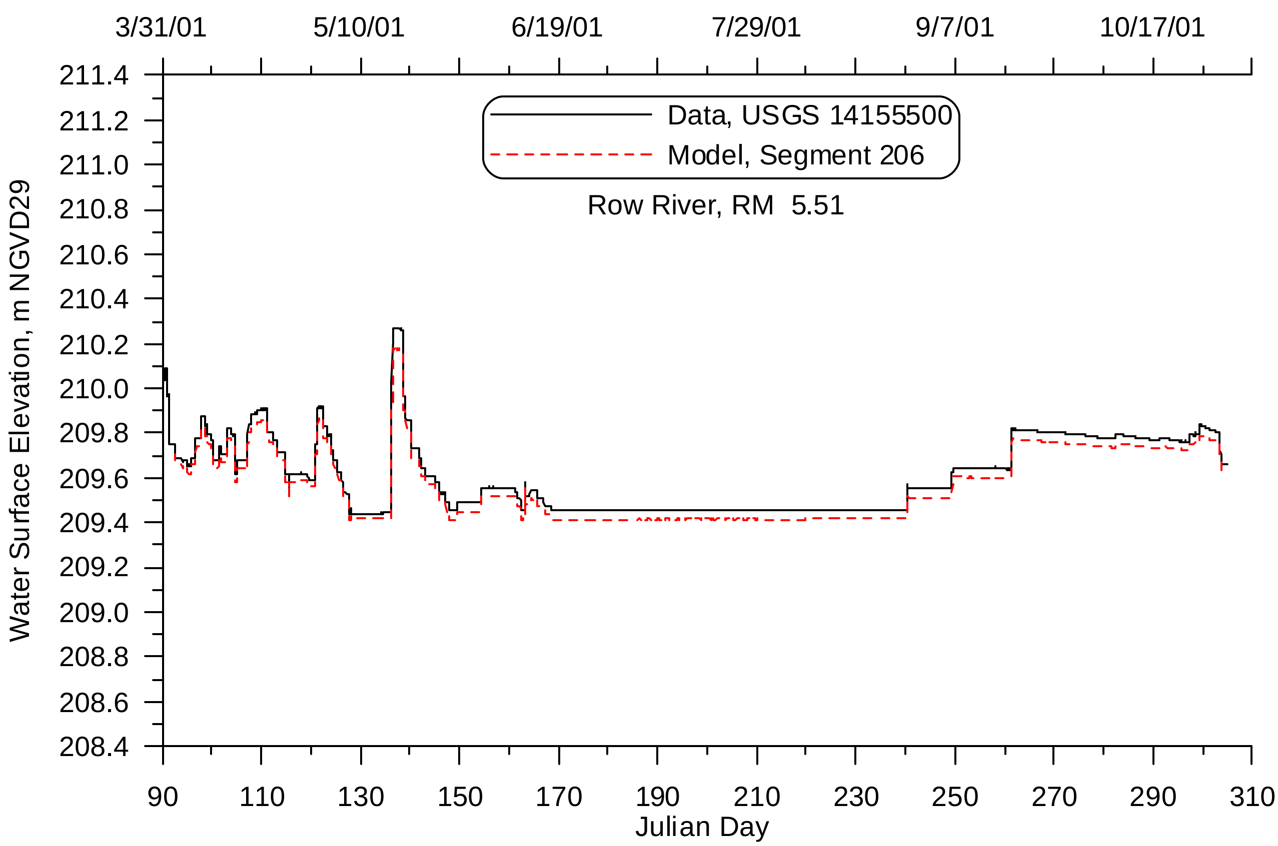

Figure 414: Row River near Cottage Grove model-data water level comparison, 2001

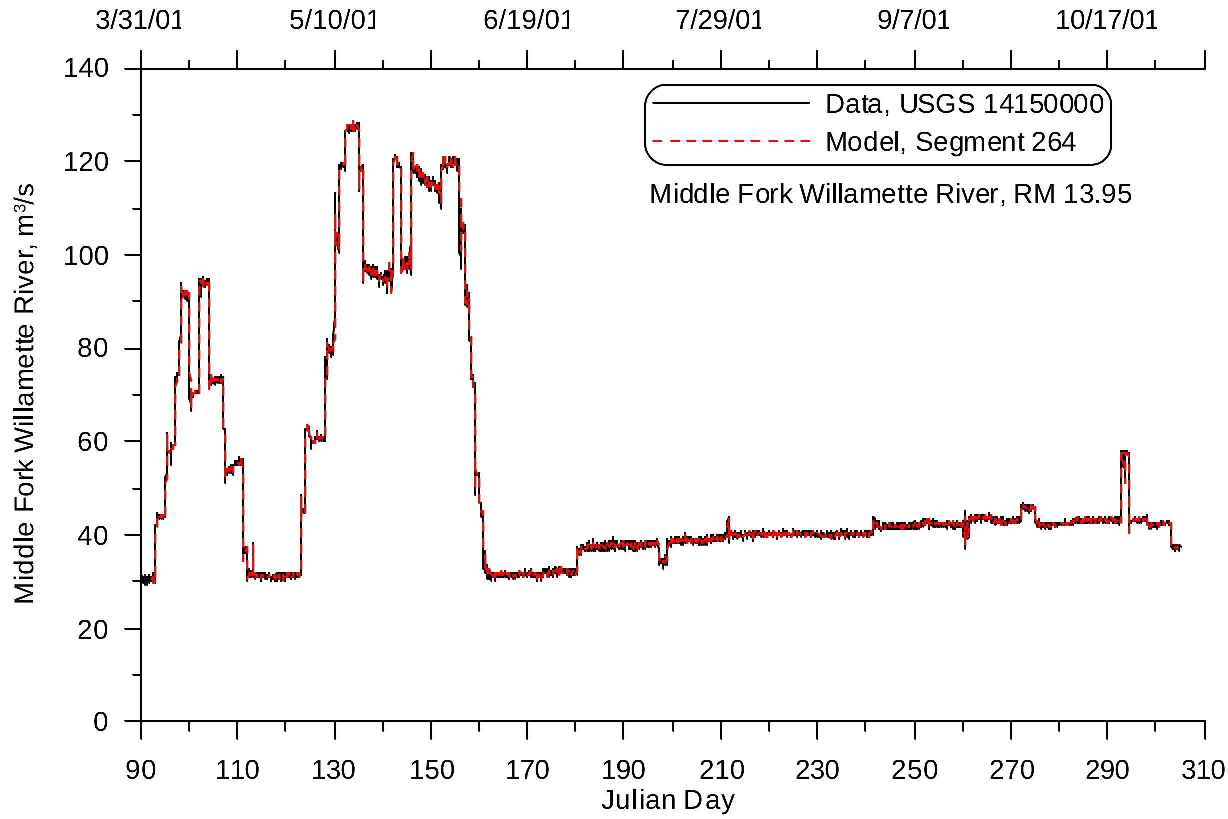

Figure 415: Middle Fork Willamette River near Dexter model-data flow comparison, 2001

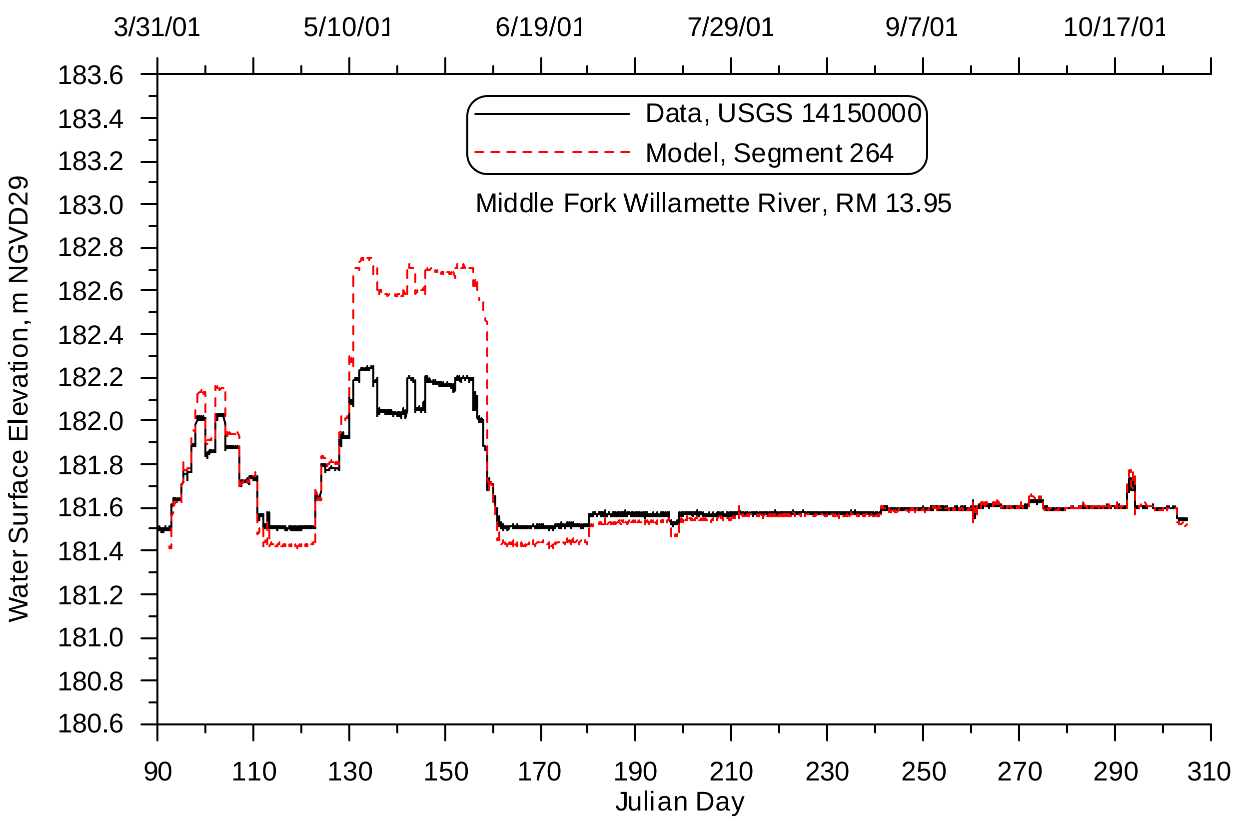

Figure 416: Middle Fork Willamette River near Dexter model-data water level comparison, 2001

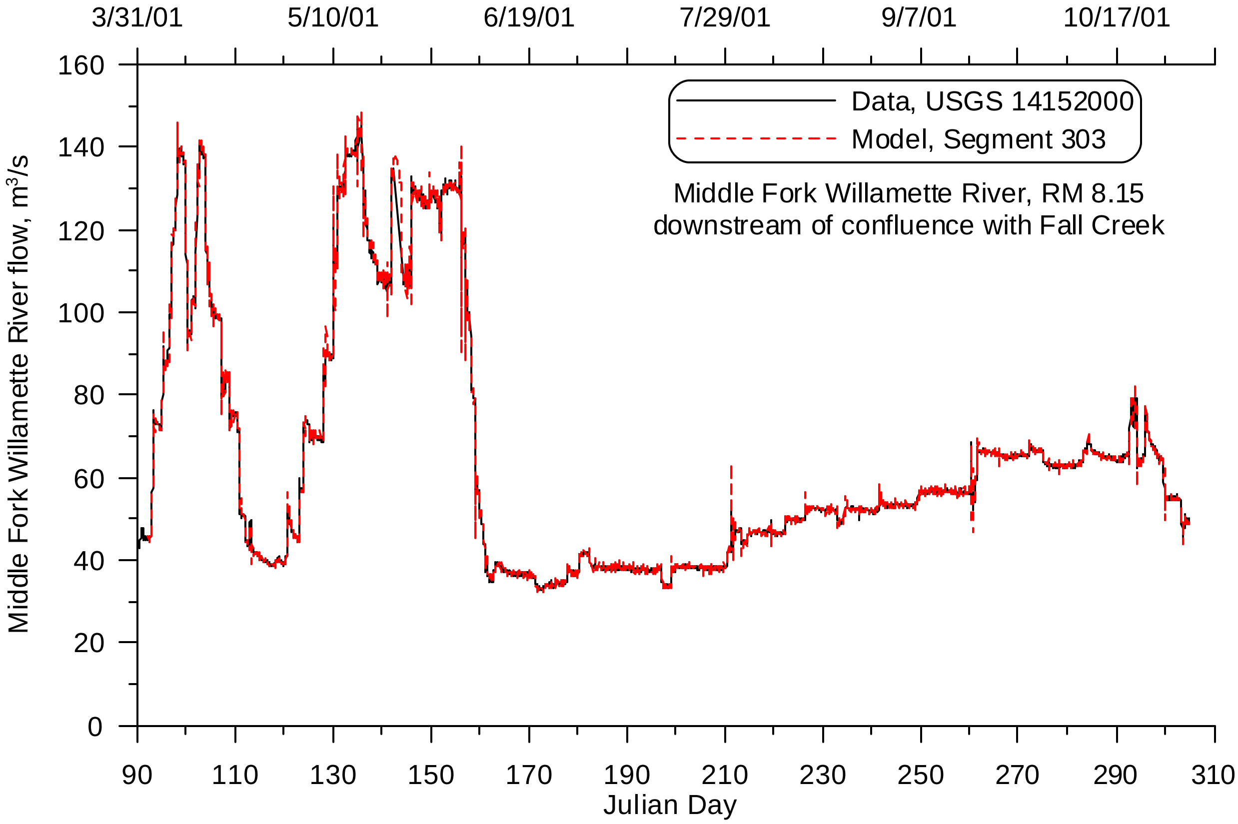

Figure 417: Middle Fork Willamette River at Jasper model-data flow comparison, 2001

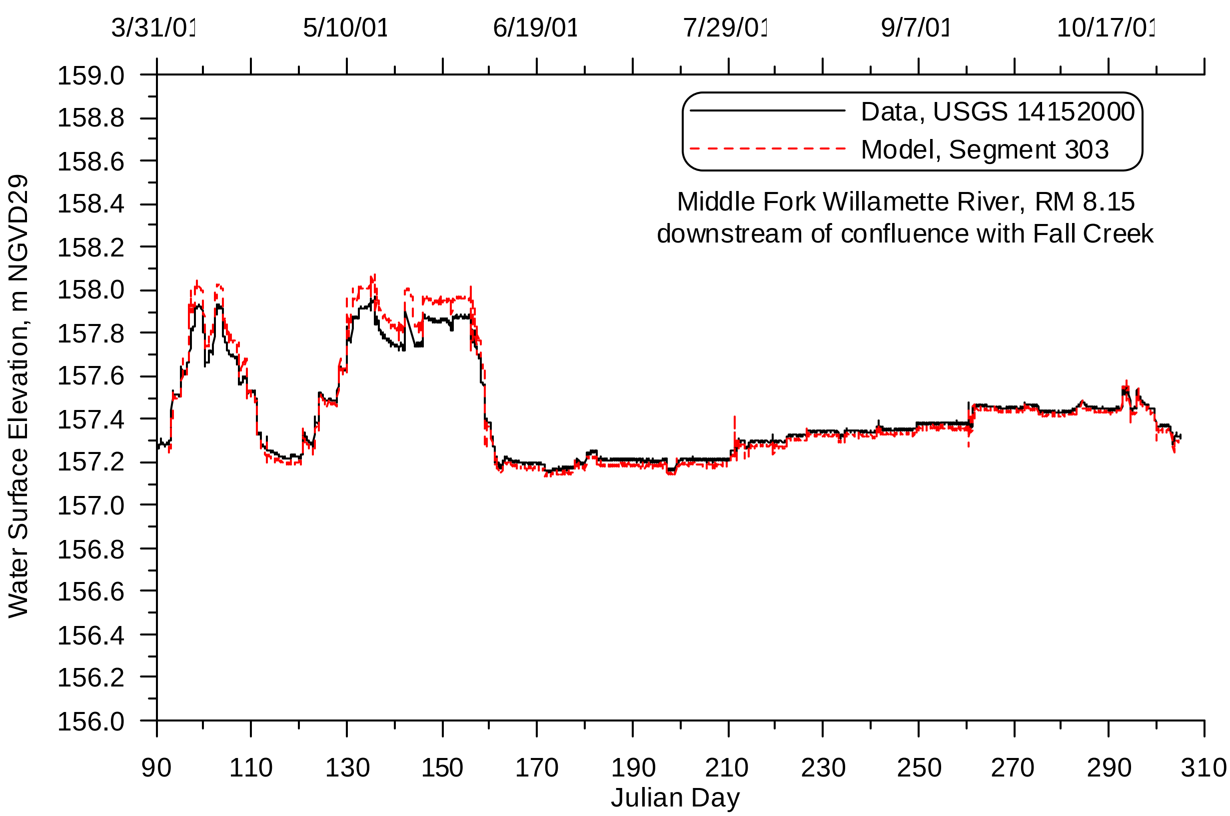

Figure 418: Middle Fork Willamette River at Jasper model-data water level comparison, 2001

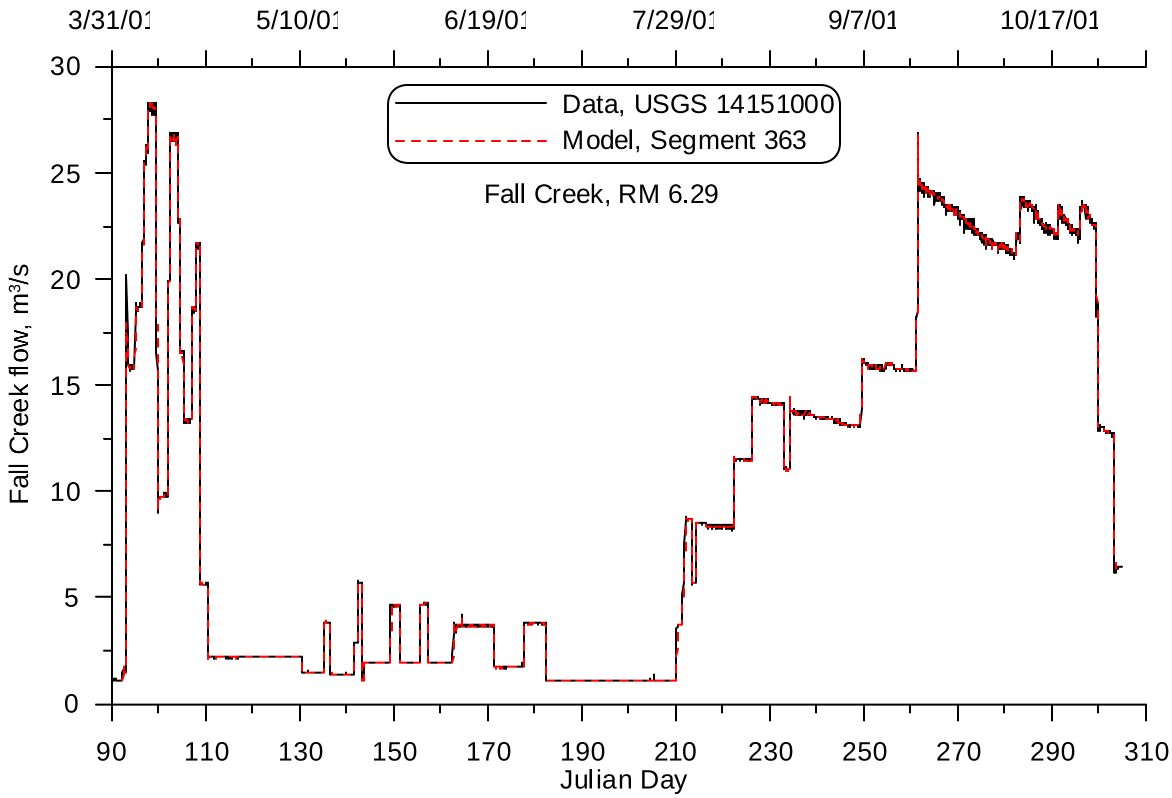

Figure 419: Fall Creek below Winberry Creek model-data flow comparison, 2001

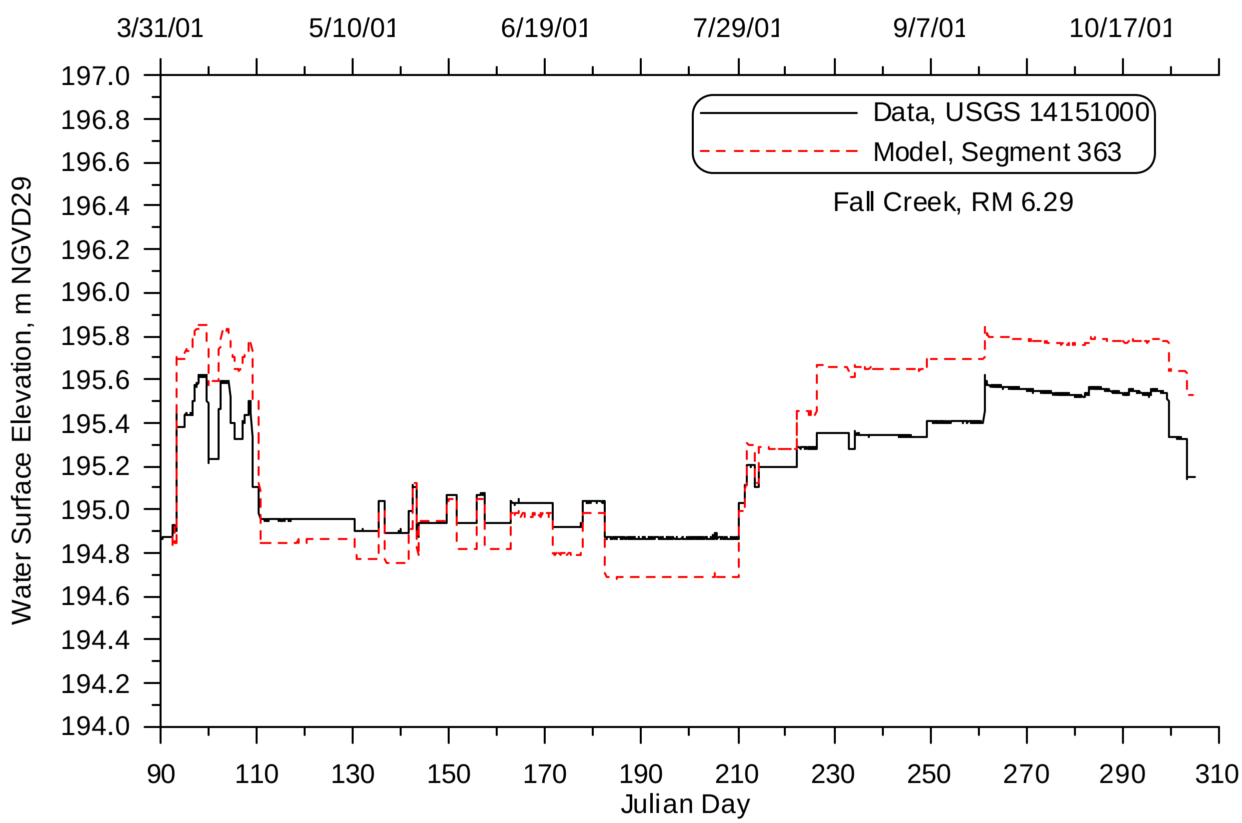

Figure 420: Fall Creek below Winberry Creek model-data water level comparison, 2001

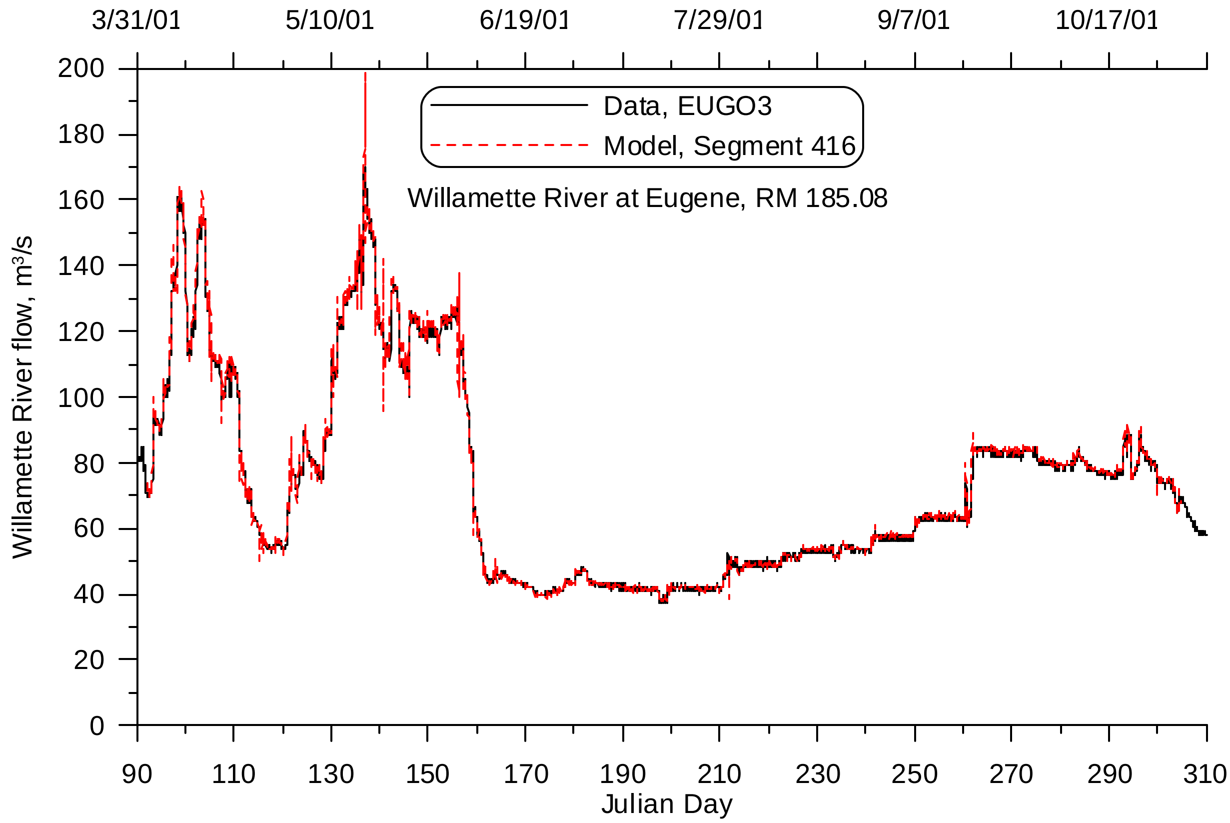

Figure 421: Flow at Eugene, ACOE EUGO3, RM 181, Segment #416

Year 2002

The hydrodynamics calibration was conducted from April to October in 2001 for both flow and water level. Table 62 lists the model-data error statistics for both flow and water level. The error statistics show good model-data agreement throughout the system for both flow and water level with the furthest downstream site (ACOE EUGO3) having the largest model-data error. The absolute mean error (AME) for flow ranged from 0.01 to 1.1 m^3/s and the root mean square error (RMS) for flow ranged from 0.05 to 2.2 m^3/s. Water level model-data error statistics ranged from 0.03 to 0.19 for AME and 0.04 to 0.21 for RMS error.

Figure 409 and Figure 410 show model-data comparison plots for the Coast Fork Willamette River below Cottage Grove Dam for flow and water level, respectively. Since this gage station is only two segments downstream from the upstream boundary condition the model flow results are expected to be close to the data. The vertical resolution of the model grid is 1 meter resulting in instances where the closest the model-data comparisons that can be achieved will fall with one model layer. In some cases the water level stays in the same model layers for most of the simulation with deviations for the lowest and highest flows. Figure 410 shows there is relatively close model-data agreement for the water level except when there is a high flow events.

Figure 411 and Figure 412 show model-data comparison plots for the Coast Fork Willamette River near Goshen (RM 5.7) for flow and water level, respectively. The gage station is downstream of where Row River enters the Coast Fork River (RM 20.12). The flow comparison figure shows several small flow spikes in the model results. These spikes are the result of low flows in the system, rapid changes in the flow regime of the model, and lack of detailed bathymetric data for the river channel.

Figure 413 and Figure 414 show model-data comparisons for the Row River for flow and water level, respectively. The upstream boundary condition for Row River is at RM 7.5 and the comparison location in 2 miles downstream at RM 5.5 so the model flow should match closely with the data. The water level results at this gage station also match closely with the data showing a small bias of under predicting water levels over the simulation period.

Figure 415 and Figure 416 show flow and water level results compared with data for the Middle Fork Willamette River near Dexter, OR. This site location is approximately 2.6 miles downstream from the upstream boundary condition so the simulated flows are expected to be close to the data. The water level results at this site show relatively good agreement with the data with the exception of the high flow period in May and June, 2001.

Figure 417 and Figure 418 show flow and water level results compared with data for the Middle Fork Willamette River at Jasper (RM 8.2) Fall Creek enters the Middle Fork Willamette River at RM 11.1. Both figures show the flow and water level model results are in good agreement with the data.

Figure 419 and Figure 420 show flow and water level results compared with data for Fall Creek at RM 6.3, which is 0.8 miles downstream from the upstream boundary condition below Fall Creek Reservoir. The flow results are close to the data as expected since it is so close to the upstream boundary condition. The water level result sat this site vary considerably for the range of flows in the river. The model does a decent job trying to simulate water levels close to data but there is some disagreement. This could be due a lack of good bathymetric data for the Fall Creek river channel. Water level variations are still within a meter and the flows simulated are following the data closely.

The furthest downstream location to compare simulated flows with data is near the city of Eugene, OR. The monitoring site is RM 181 and the furthest downstream location of the Coast and Middle Fork model is RM 185.1. Figure 421 compares the simulated flows at RM 185.1 and data from RM 181 and indicates there is good model-data agreement. The close agreement between the model and data indicates the Coast and Middle Fork model is simulating the appropriate quantity of water over time and passing it downstream to the Upper Willamette Model.

Table 63: Coast and Middle Fork Willamette River hydrodynamic calibration model-data error statistics, 2002

Flow						
Gage ID	RM	Model Segment	Sample size, N	Mean Error, m^3/s	Absolute ME, m^3/s	RMS Error, m^3/s
USGS 14153500	28.69	4	10174	0.00	0.01	0.10
USGS 14157500	5.72	153	9391	-0.08	0.27	1.00
USGS 14155500	5.51	206	10174	0.00	0.04	0.36
USGS 14150000	13.95	264	10173	0.01	0.34	0.89
USGS 14152000	8.15	303	10173	-0.05	0.38	1.77
USGS 14151000	6.29	363	10173	0.00	0.05	0.26
ACOE EUGO3	185.08	416	10020	0.00	0.67	2.18
Water Level						

Gage ID	RM	Model Segment	Sample size, N	Mean Error, m	Absolute ME, m	RMS Error, m
USGS 14153500	28.69	4	10174	-0.04	0.15	0.19
USGS 14157500	5.72	153	9389	-0.01	0.02	0.03
USGS 14155500	5.51	206	10174	-0.03	0.04	0.04
USGS 14150000	13.95	264	10173	0.07	0.09	0.11
USGS 14152000	8.15	303	10173	0.03	0.06	0.08
USGS 14151000	6.29	363	10173	0.06	0.13	0.18
ACOE EUGO3	185.08	416	Not a valid comparison since the site is downstream of the model domain			

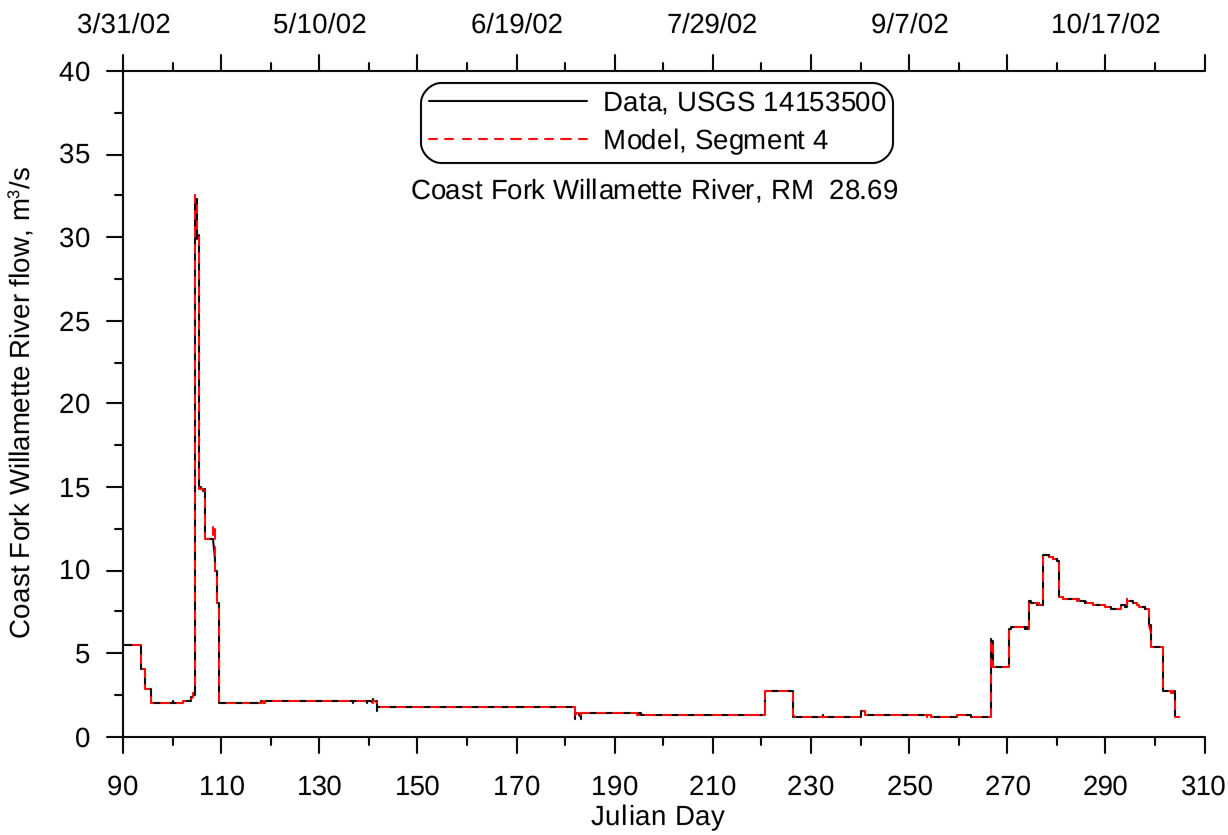

Figure 422: Coast Fork Willamette River below Cottage Grove Dam model-data flow comparison, 2002

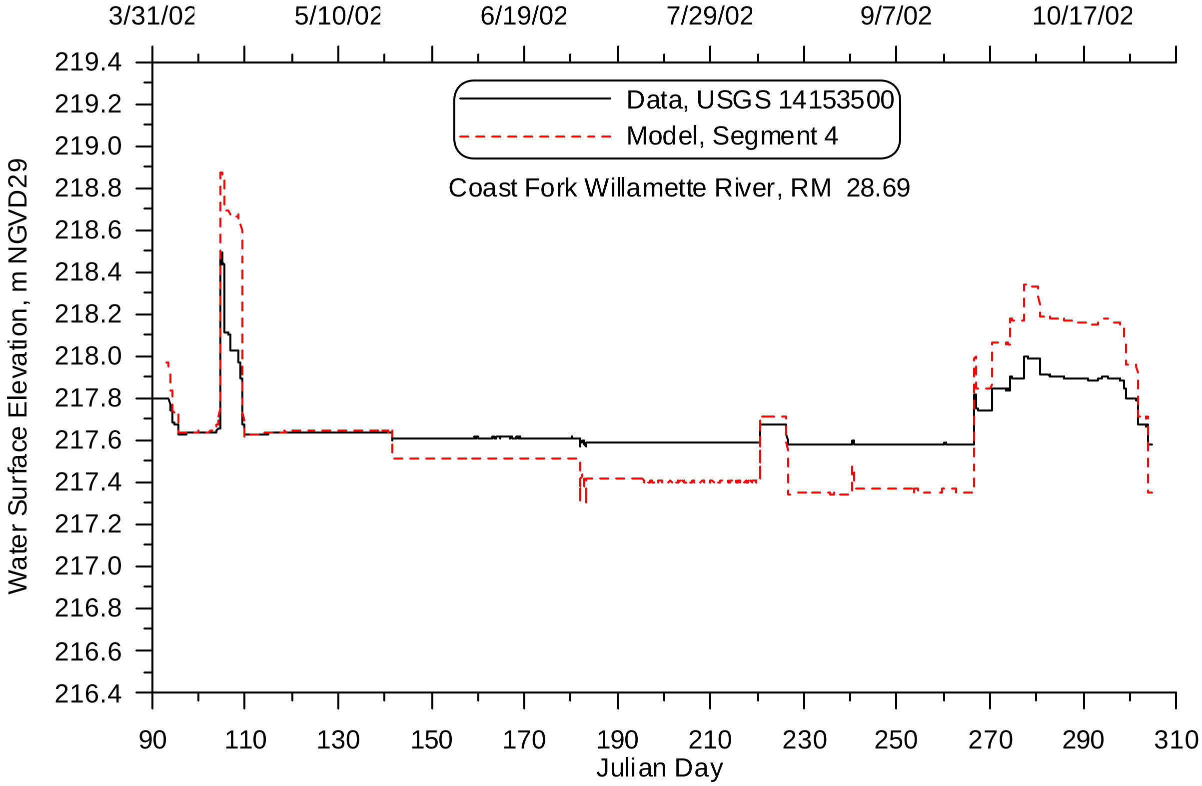

Figure 423: Coast Fork Willamette River below Cottage Grove Dam model-data water level comparison, 2002

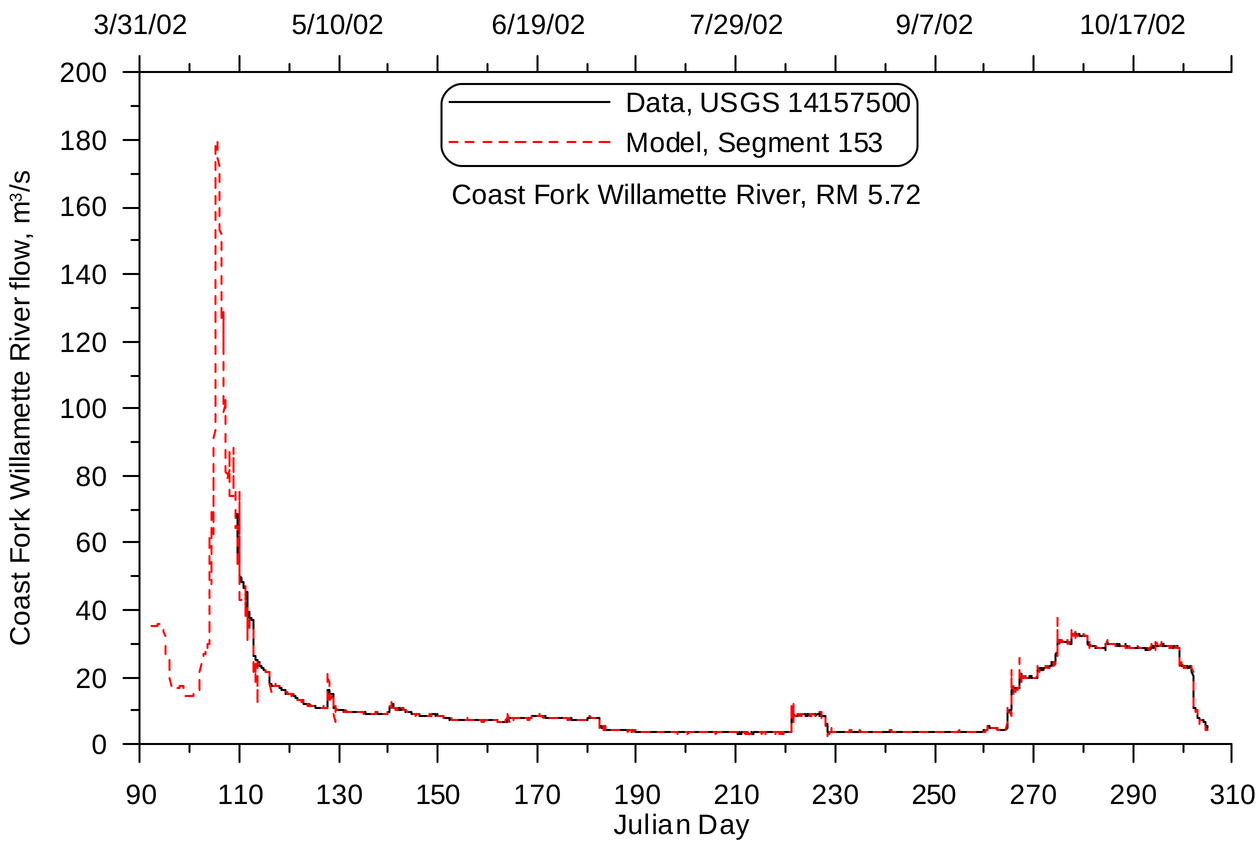

Figure 424: Coast Fork Willamette River near Goshen model-data flow comparison, 2002

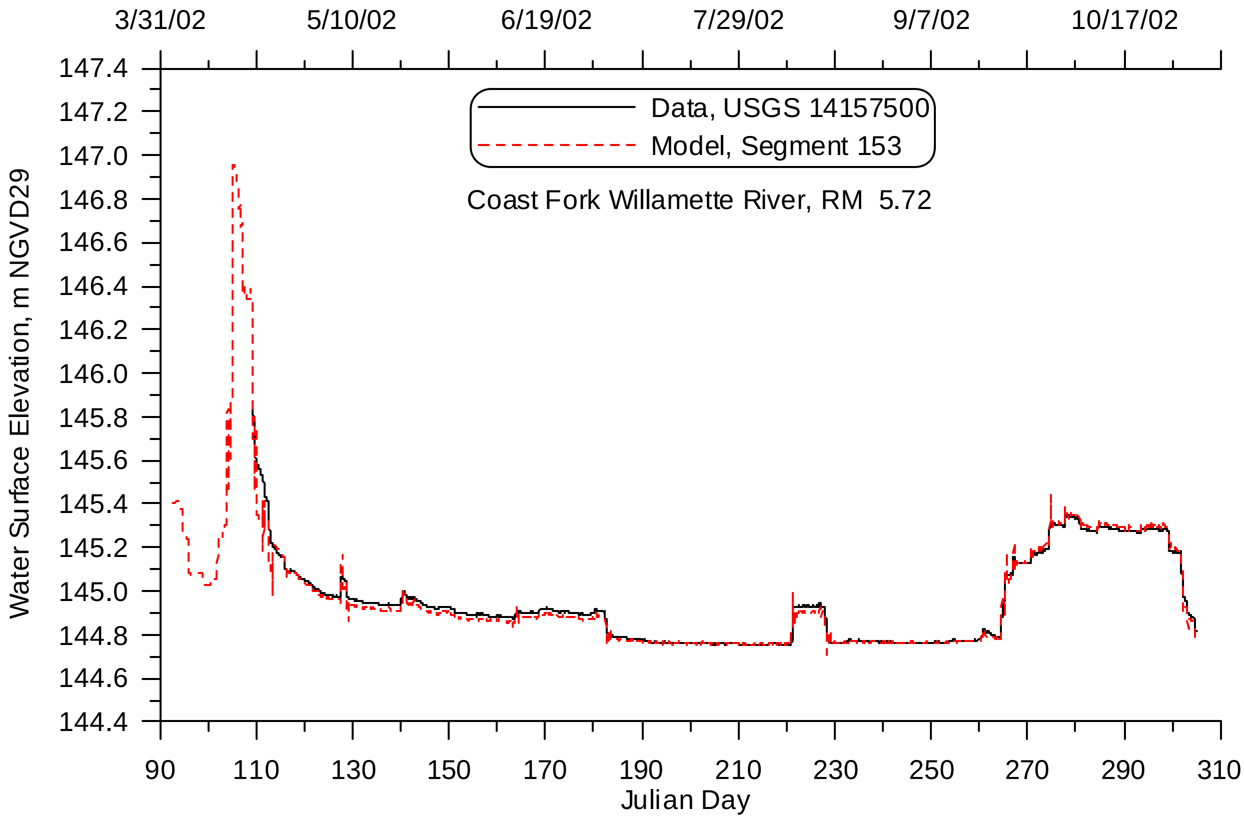

Figure 425: Coast Fork Willamette River near Goshen model-data water level comparison, 2002

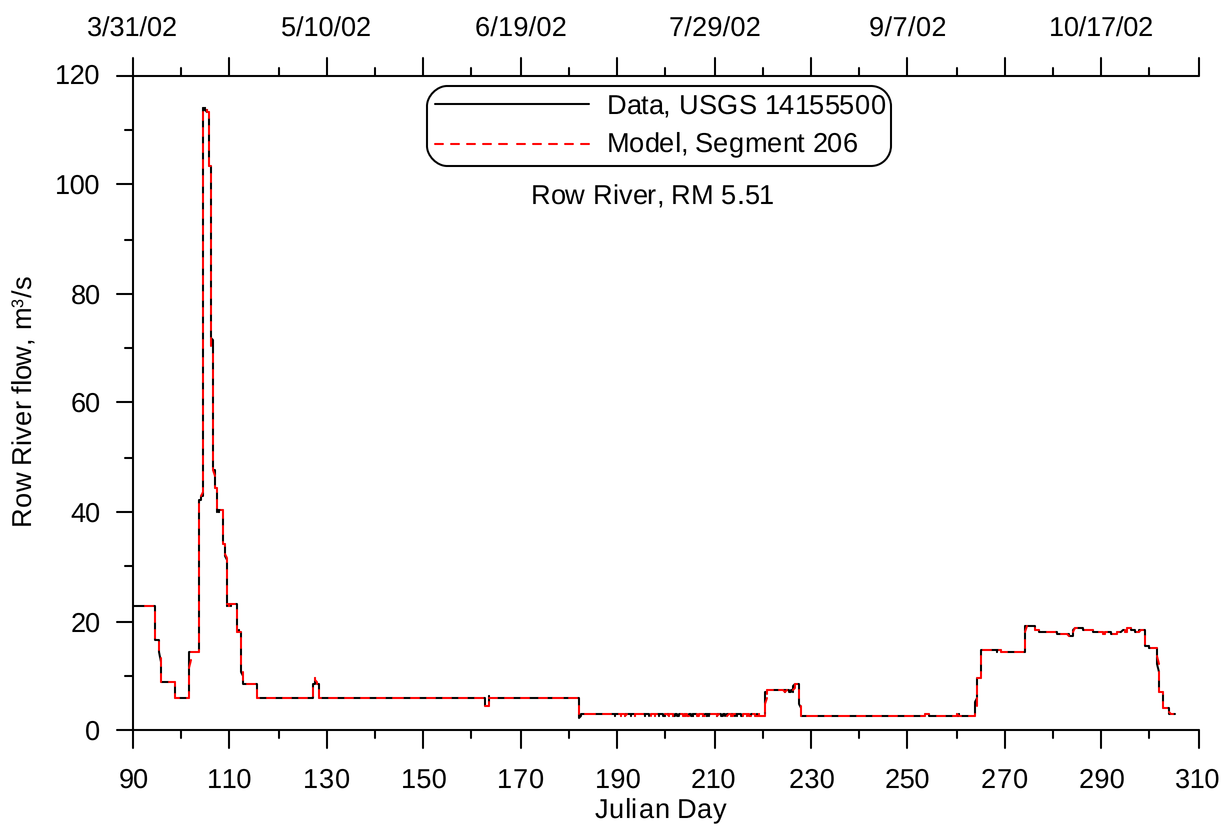

Figure 426: Row River near Cottage Grove model-data flow comparison, 2002

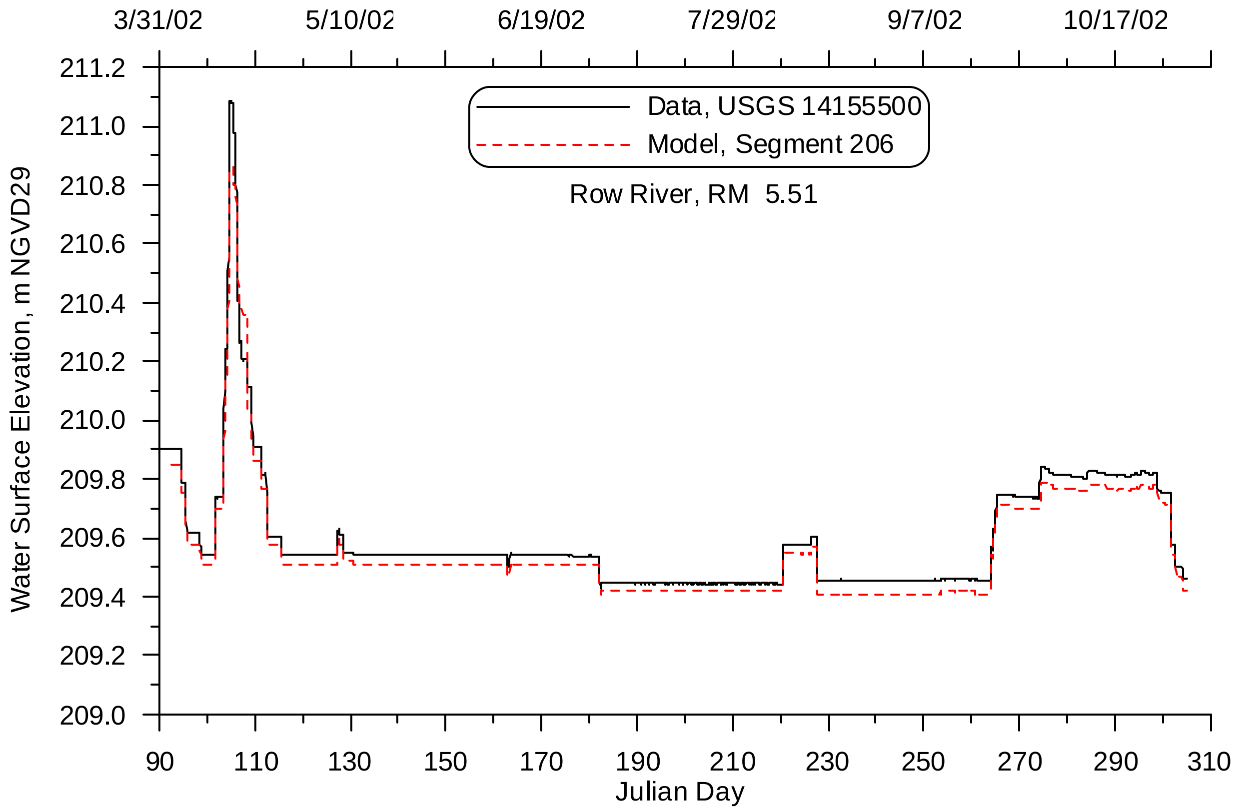

Figure 427: Row River near Cottage Grove model-data water level comparison, 2002

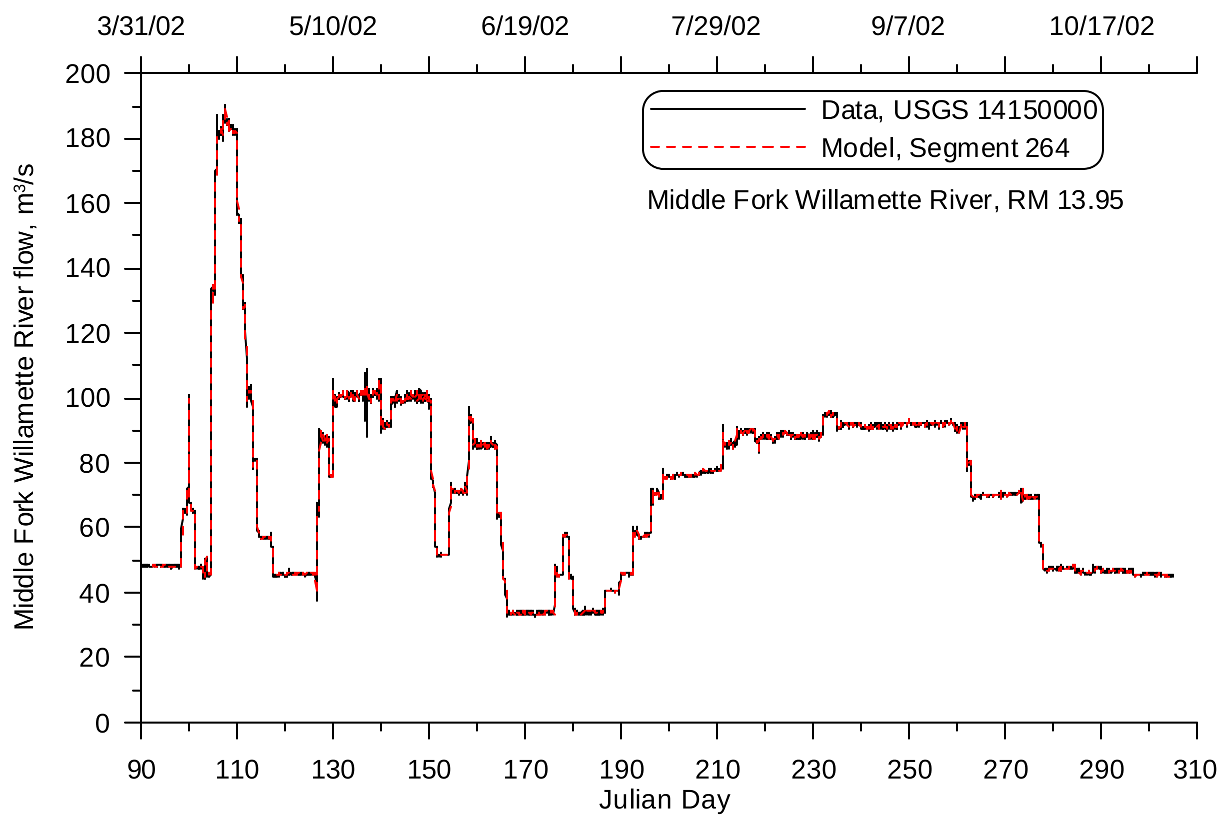

Figure 428: Middle Fork Willamette River near Dexter model-data flow comparison, 2002

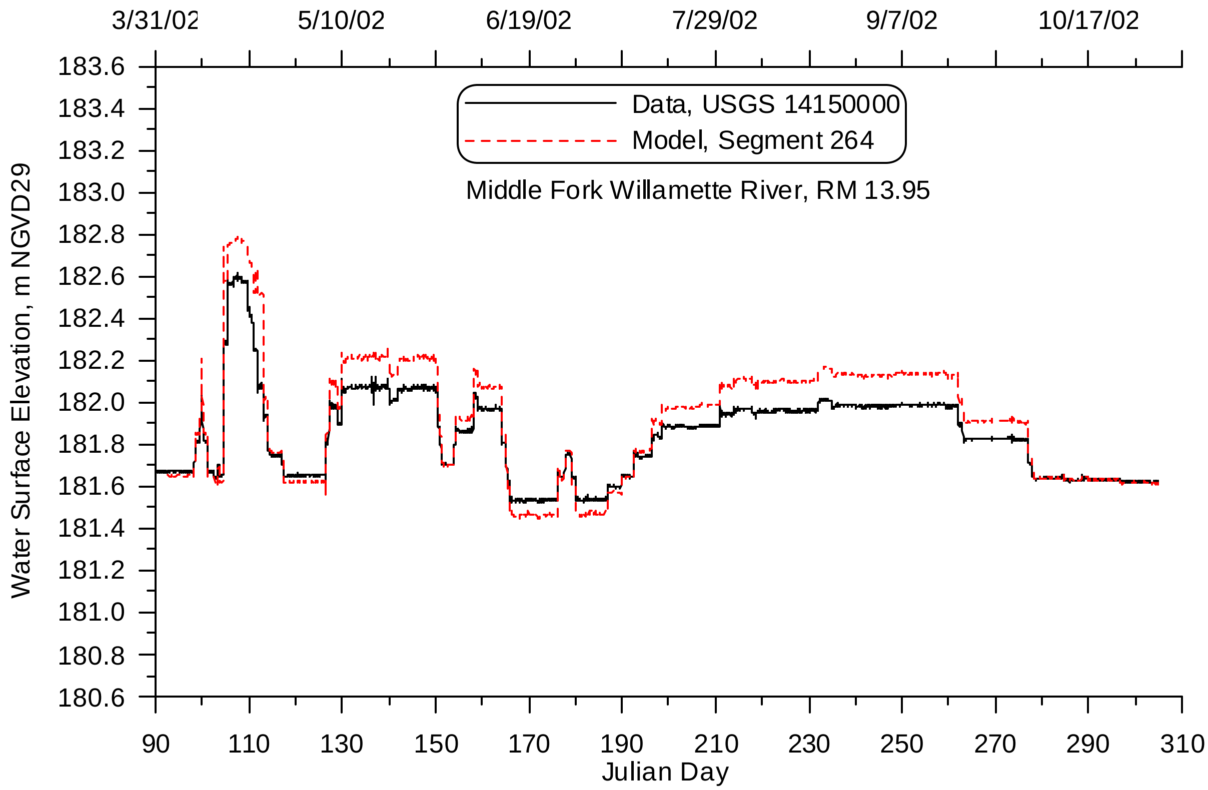

Figure 429: Middle Fork Willamette River near Dexter model-data water level comparison, 2002

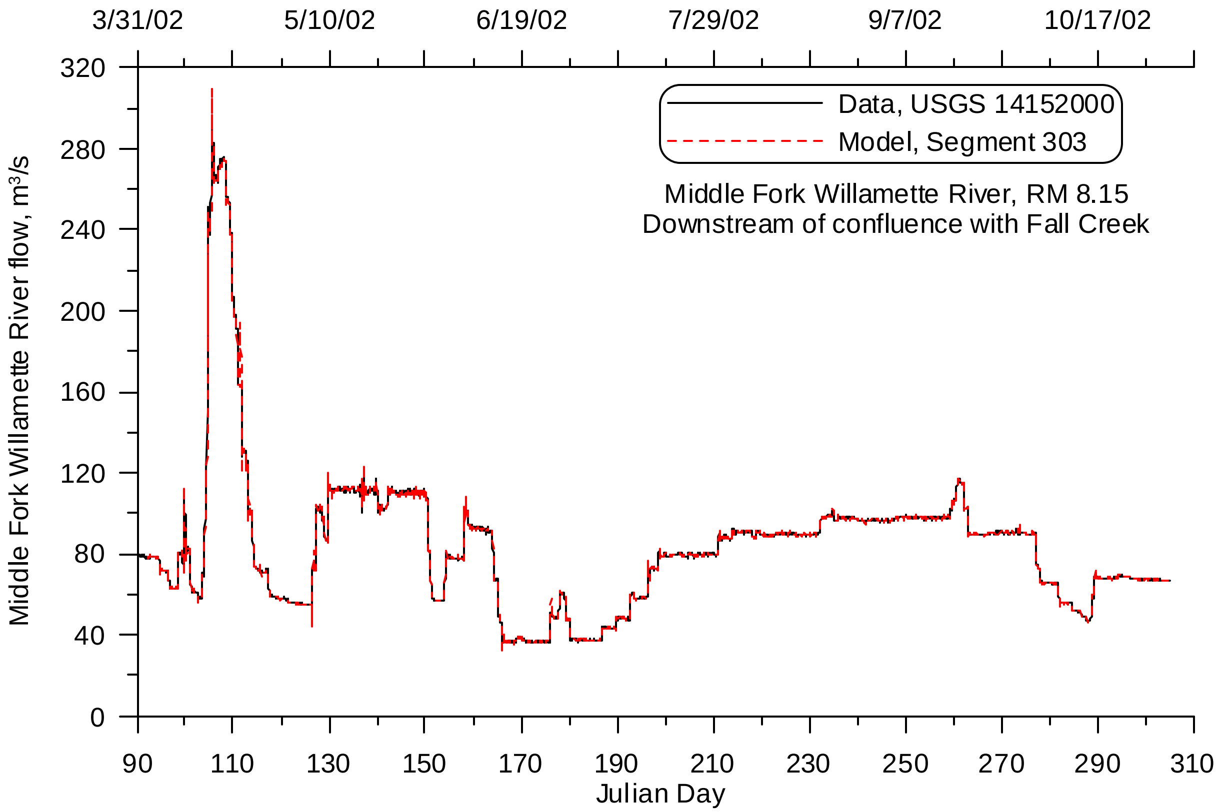

Figure 430: Middle Fork Willamette River at Jasper model-data flow comparison, 2002

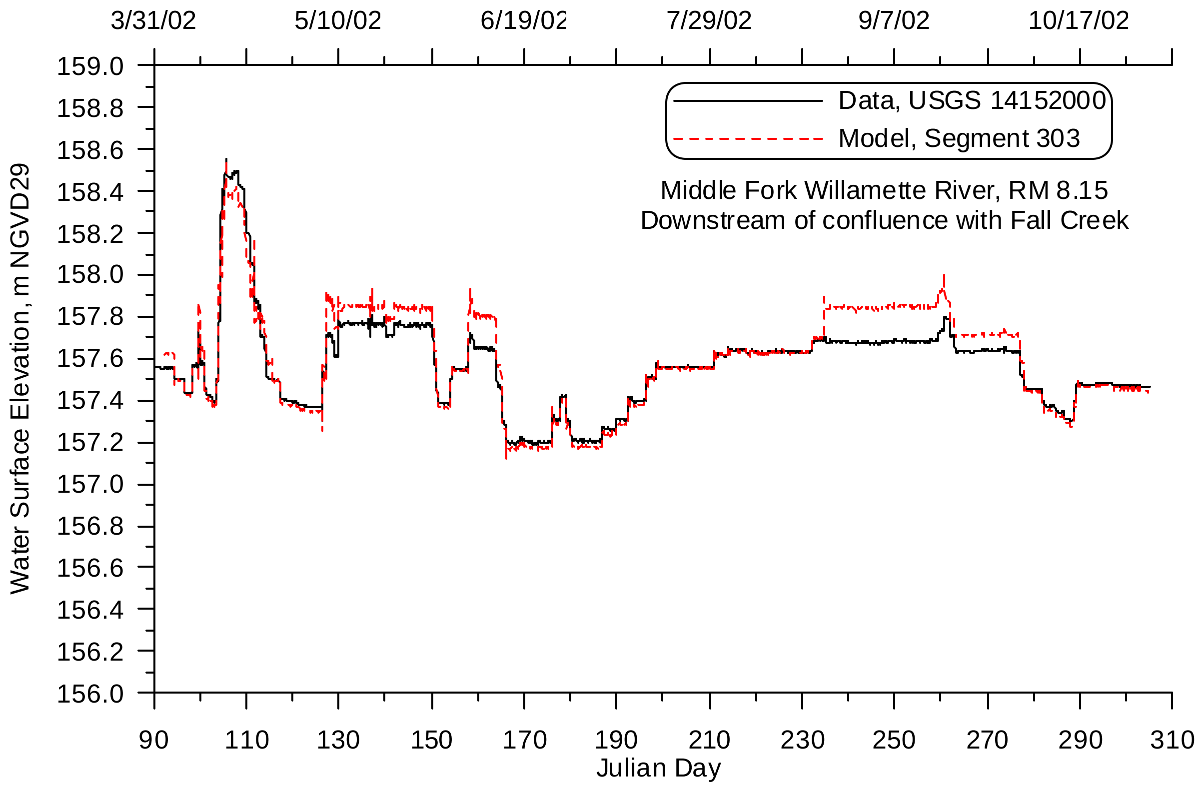

Figure 431: Middle Fork Willamette River at Jasper model-data water level comparison, 2002

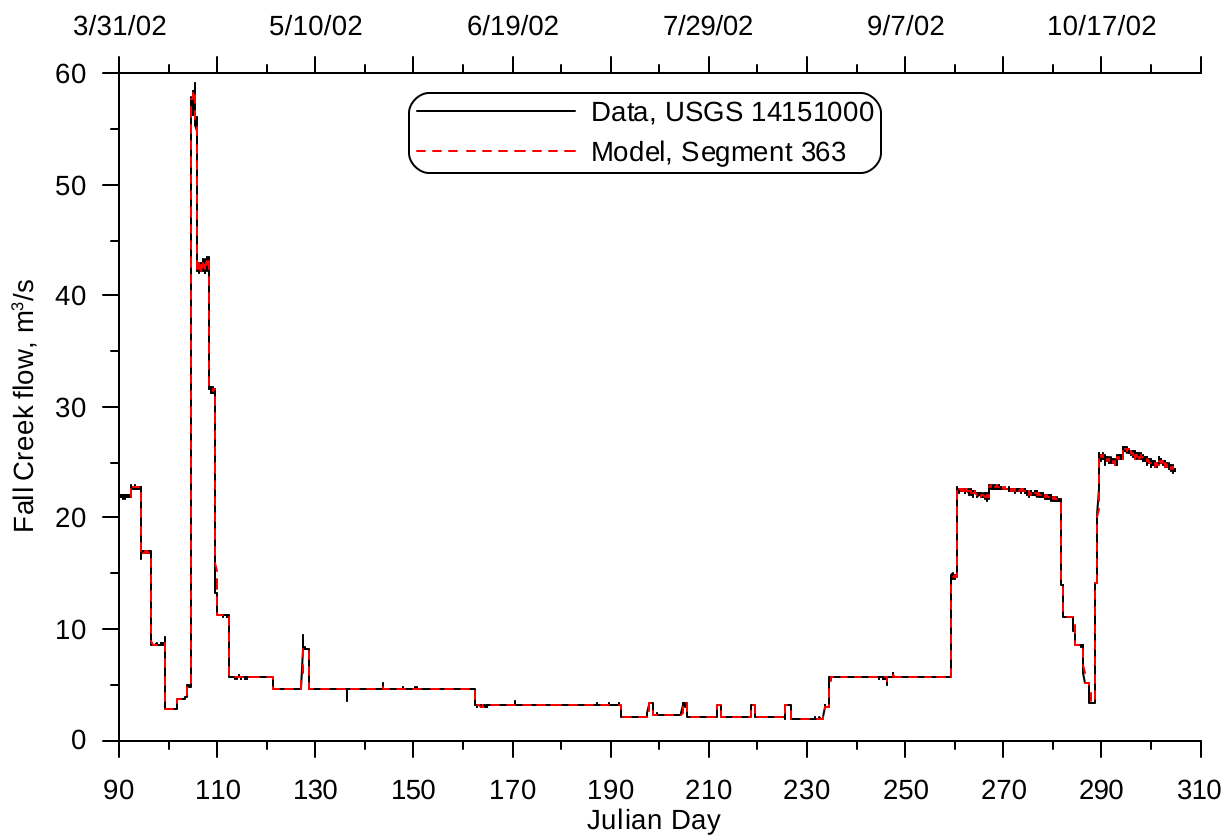

Figure 432: Fall Creek below Winberry Creek model-data flow comparison, 2002

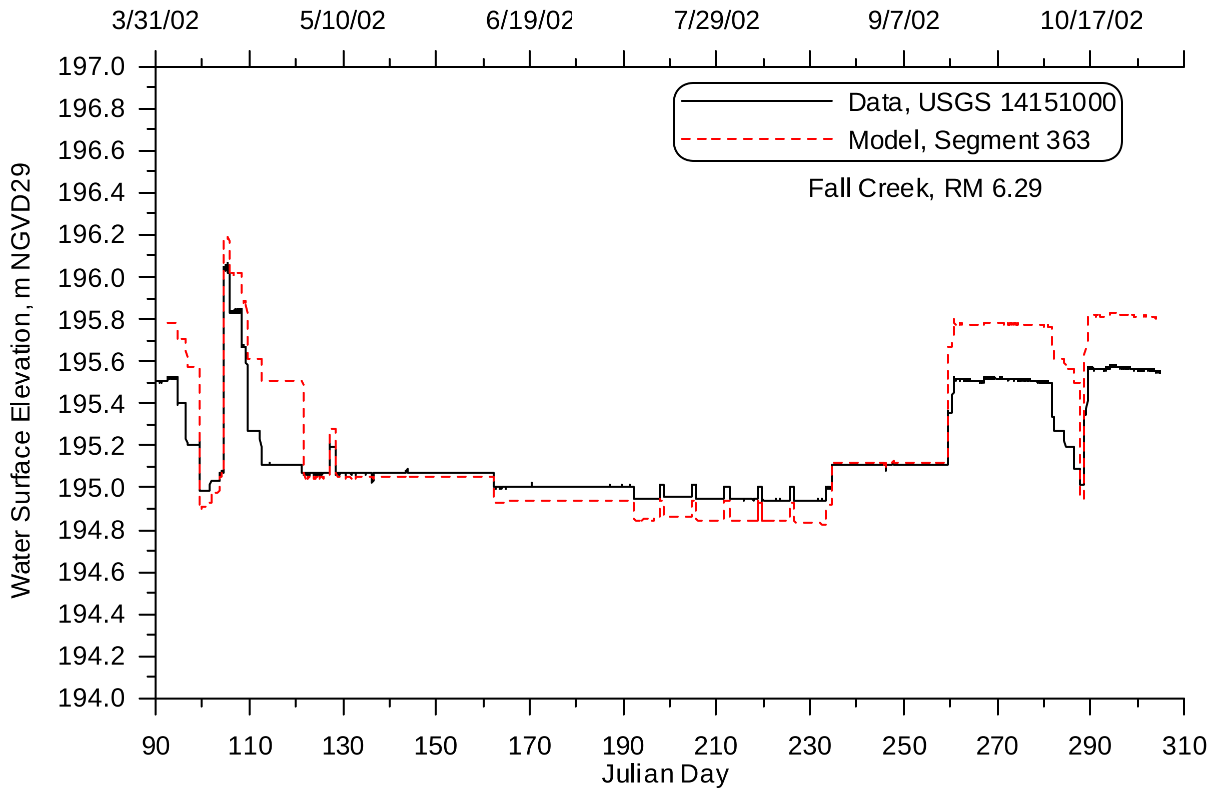

Figure 433: Fall Creek below Winberry Creek model-data water level comparison, 2002

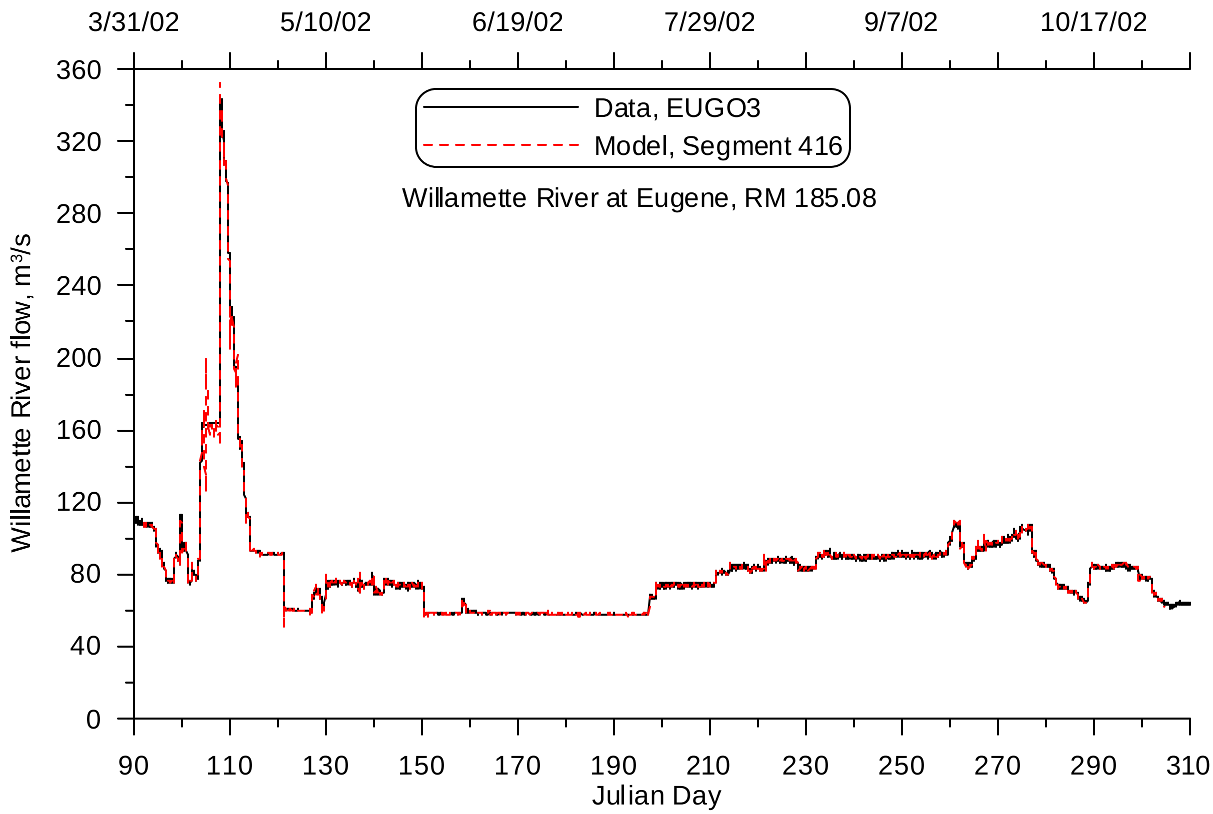

Figure 434: Willamette River at Eugene model-data flow comparison, 2001. Gage station used: ACOE EUGO3 at RM 181.

Water Balance Flows

Year 2001

Distributed tributary flows on Coast Fork and Middle Fork Willamette Rivers were divided into five tributaries rather than distributed over model branches due to the locations of gage stations used for calibration. Table 64 lists the water temperature file records used for each of the water balance flow files used in the model.

Table 64: Water balance (distributed) tributary temperatures, 2001

Water Balance Distributed Tributary	Temperature Data
Coast Fork Willamette River, Branch 1	Coast Fork River upstream boundary conditions
Middle Fork Willamette River, Branch 7	Middle Fork River gage USGS: 14152000
Fall Creek, Branch 9	Fall Creek upstream boundary condition
Willamette River to Eugene, Branch 10	Middle Fork River gage USGS: 14152000

The Coast Fork Willamette River water balance flows were incorporated as tributaries to model segments 100 to 104. Row River enters the Coast Fork Willamette River at model segment 58 and the two USGS gage stations are located at model segments 4 (USGS 14153500) and 153 (USGS 14157500). The average flow in 2001 was 0.9 m^3/s or 5.9 % of the river flow. Figure 435 shows the water balance flow for the Coast Fork Willamette River.

The Middle Fork Willamette River water balance flows were incorporated as tributaries to model segments 270 to 274. Fall Creek enters the Middle Fork Willamette River at model segment 284 and the two USGS gage stations are located at model segments 264 (USGS 14150000) and 303 (USGS 14152000). The average flow in 2001 was 3.1 m^3/s or 4.8% of river flow. Figure 436 shows the water balance flow for the Middle Fork Willamette River.

The Fall Creek water balance flows were incorporated as a tributary to the model at segment 380 which is downstream of the USGS gage station 14151000 at model segment 363. The average flow was 0.6 m^3/s or 6.5 % of river flow. Figure 437 shows the water balance flow for Fall Creek.

The Willamette River water balance between confluence of the Coast Fork and Middle Fork and the downstream boundary condition was incorporated as a distributed tributary. The average flow was -6.7 m^3/s or -9.1 % of the river flow. Figure 438 shows the water balance flow for the Willamette River.

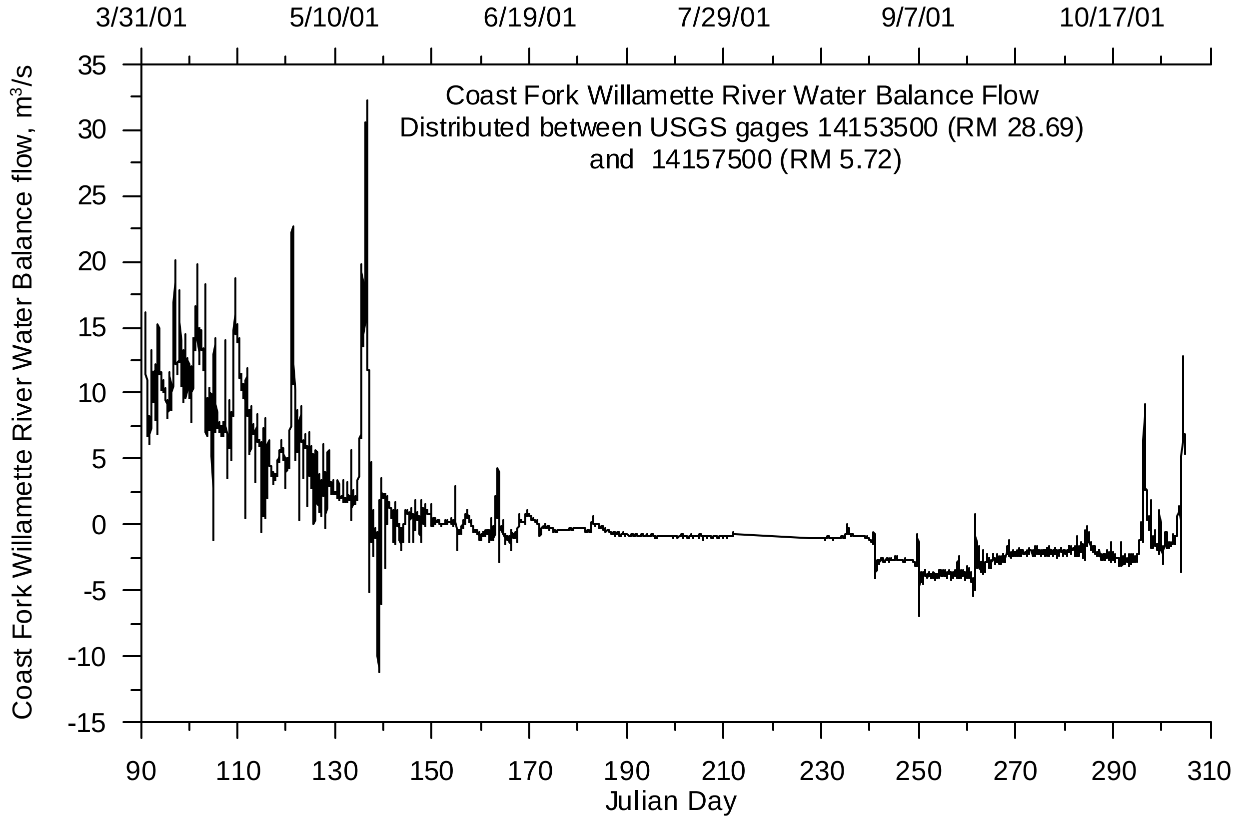

Figure 435: Coast Fork Willamette River water balance flow, 2001

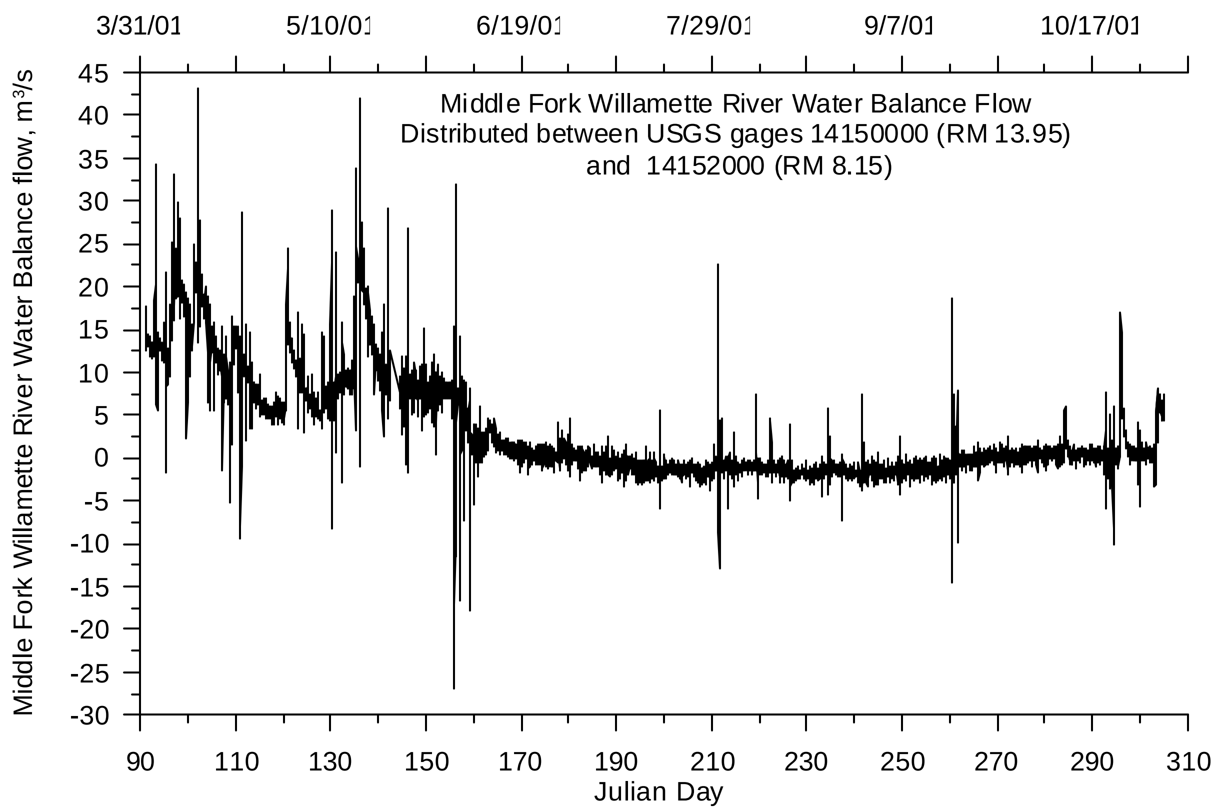

Figure 436: Middle Fork Willamette River water balance flow, 2001

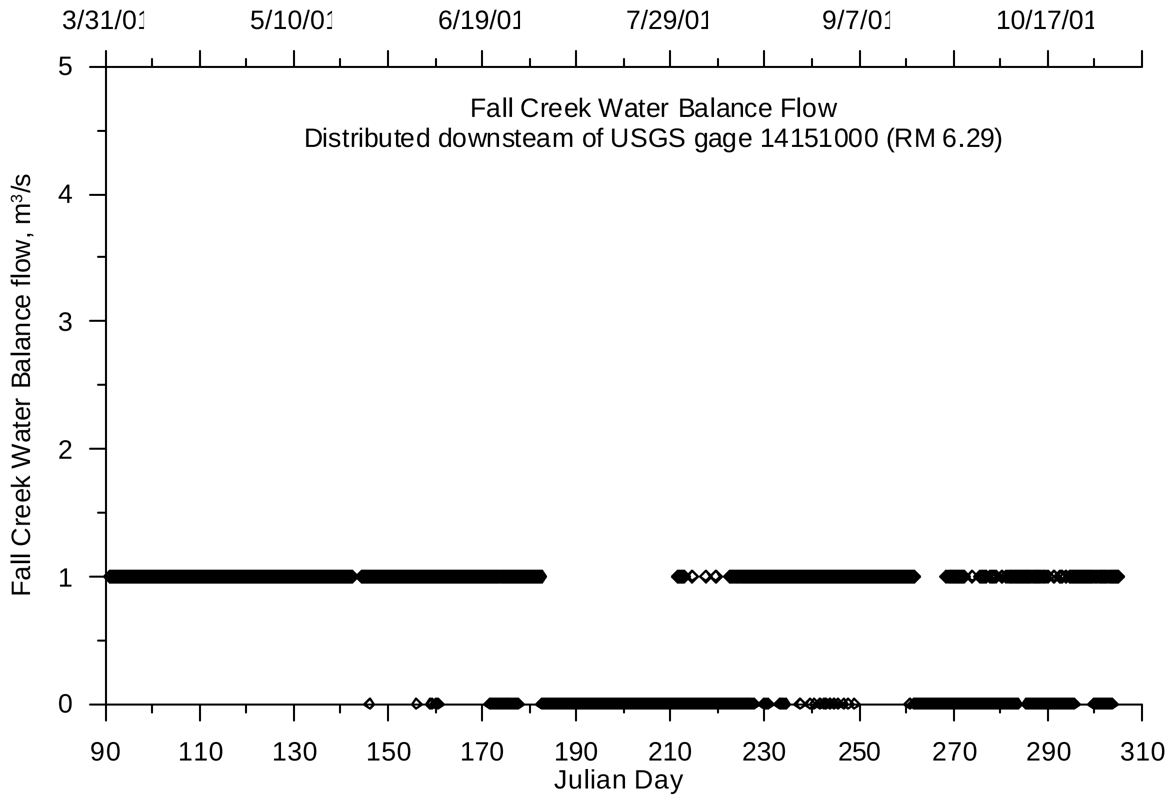

Figure 437: Fall Creek water balance flow, 2001

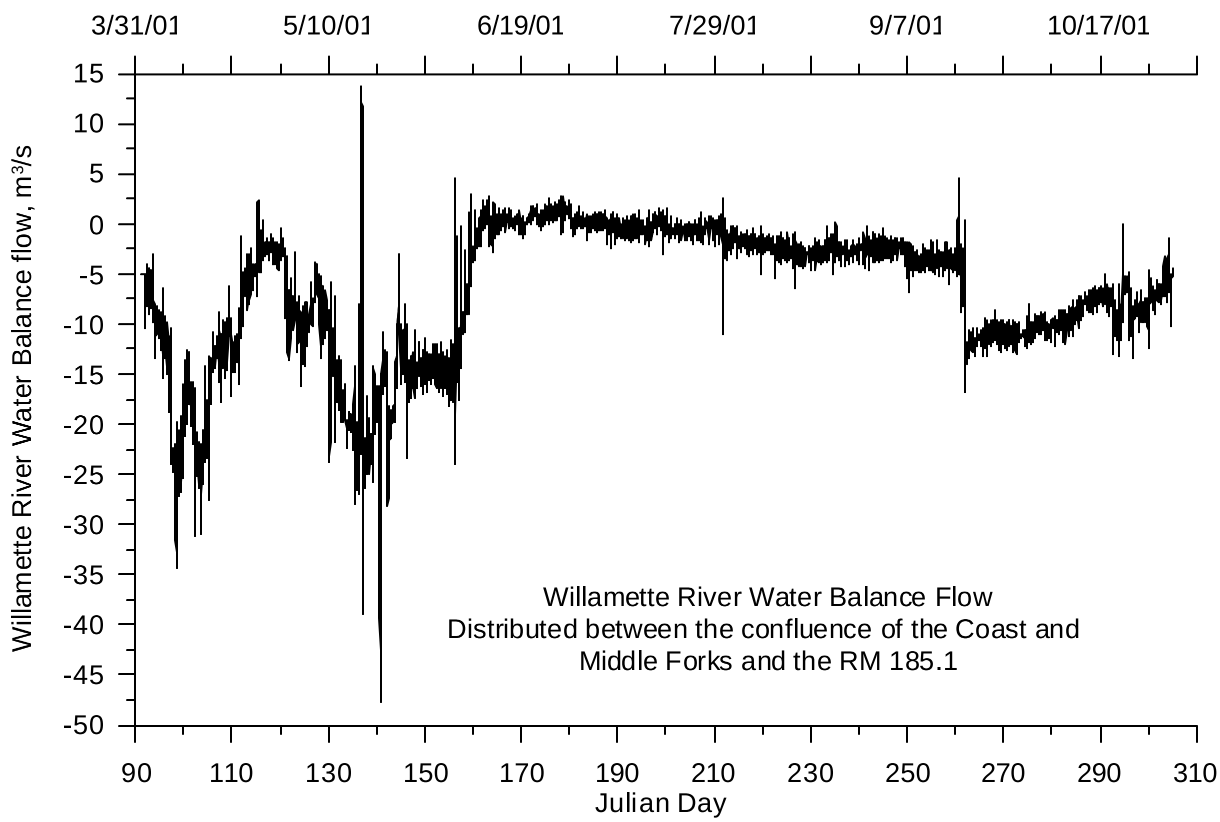

Figure 438: Willamette River water balance flow, 2001

Year 2002

Distributed tributary flows on Coast Fork and Middle Fork Willamette Rivers were divided into five tributaries rather than distributed over model branches due to the locations of gage stations used for calibration. Table 63 lists the water temperature file records used for each of the water balance flow files used in the model.

Table 65: Distributed tributary temperatures, 2002

Distributed Tributary	Temperature Data Record
Coast Fork Willamette River, Branch 1	Coast Fork River upstream boundary conditions
Middle Fork Willamette River, Branch 7	Middle Fork River gage USGS: 14152000
Fall Creek, Branch 9	Fall Creek upstream boundary condition
Willamette River to Eugene, Branch 10	Middle Fork River gage USGS: 14152000

The Coast Fork Willamette River water balance flows were incorporated as tributaries to model segments 100 to 104. The total average flow was -0.7 m^3/s or -5.8 % of river flow. Figure 439 shows the water balance flow for the Coast Fork Willamette River.

The Middle Fork Willamette River water balance flows were incorporated as tributaries to model segments 270 to 274. The total average flow was 2.7 m^3/s or 3.3% of river flow. Figure 440 shows the water balance flow for the Middle Fork Willamette River.

The Fall Creek water balance flows were incorporated as a tributary to the model at segment 380. The total average flow was 0.7 m^3/s or 7.2 % of river flow. Figure 441 shows the water balance flow for Fall Creek.

The Willamette River water balance between confluence of the Coast Fork and Middle Fork and the downstream boundary condition was incorporated as a distributed tributary. The total average flow was -16.8 m^3/s or -20.3 % of the river flow. Figure 442 shows the water balance flow for the Willamette River.

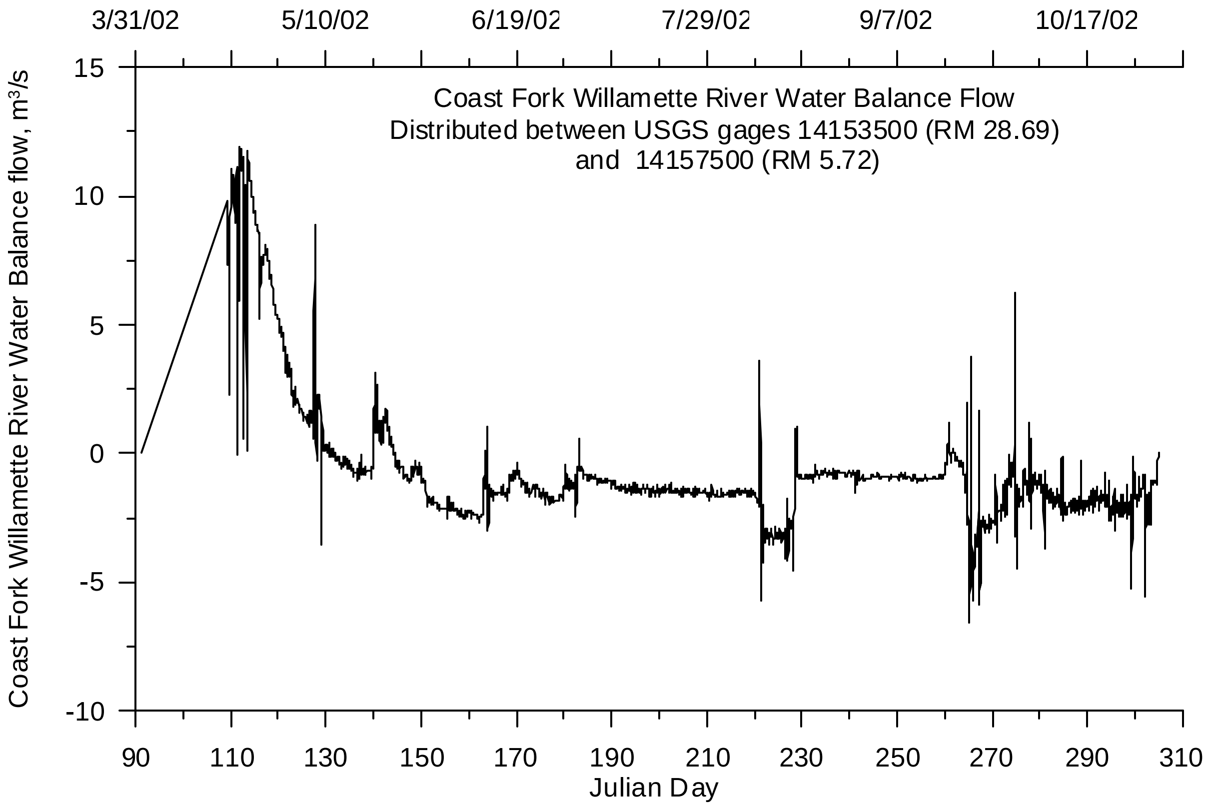

Figure 439: Coast Fork Willamette River water balance flow, 2002

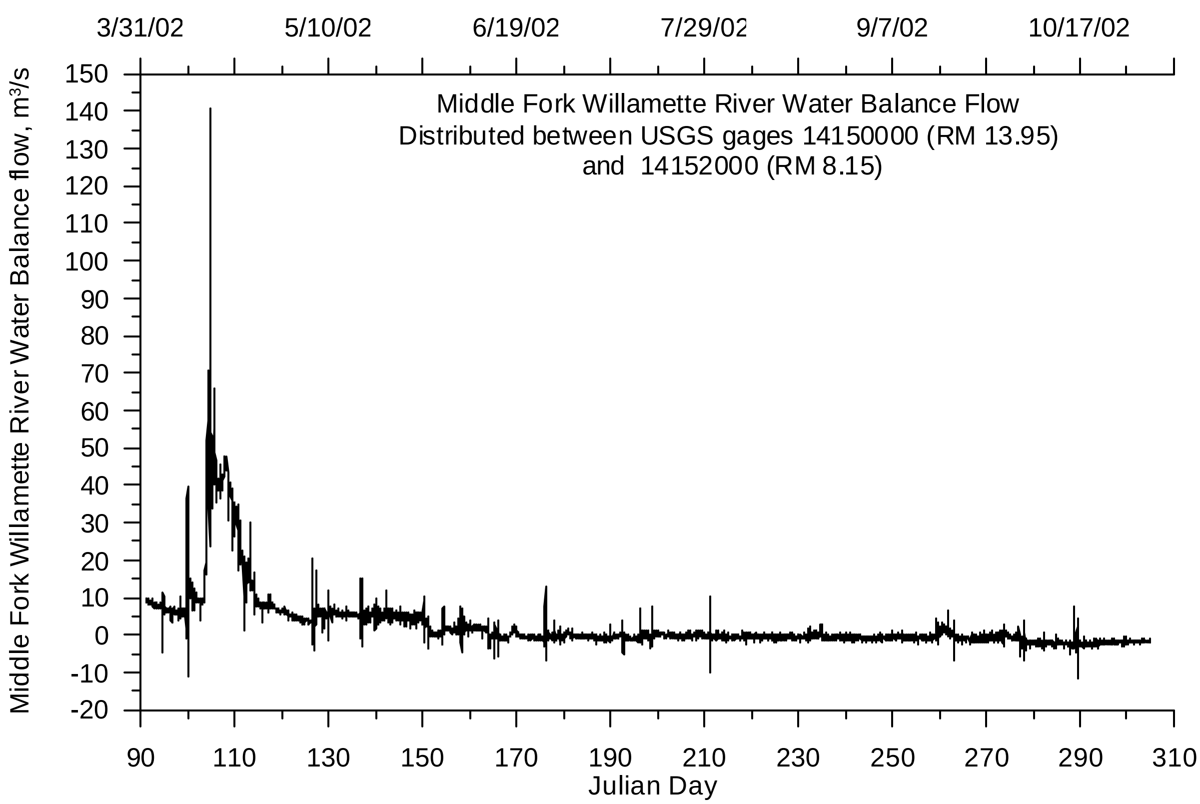

Figure 440: Middle Fork Willamette River water balance flow, 2002

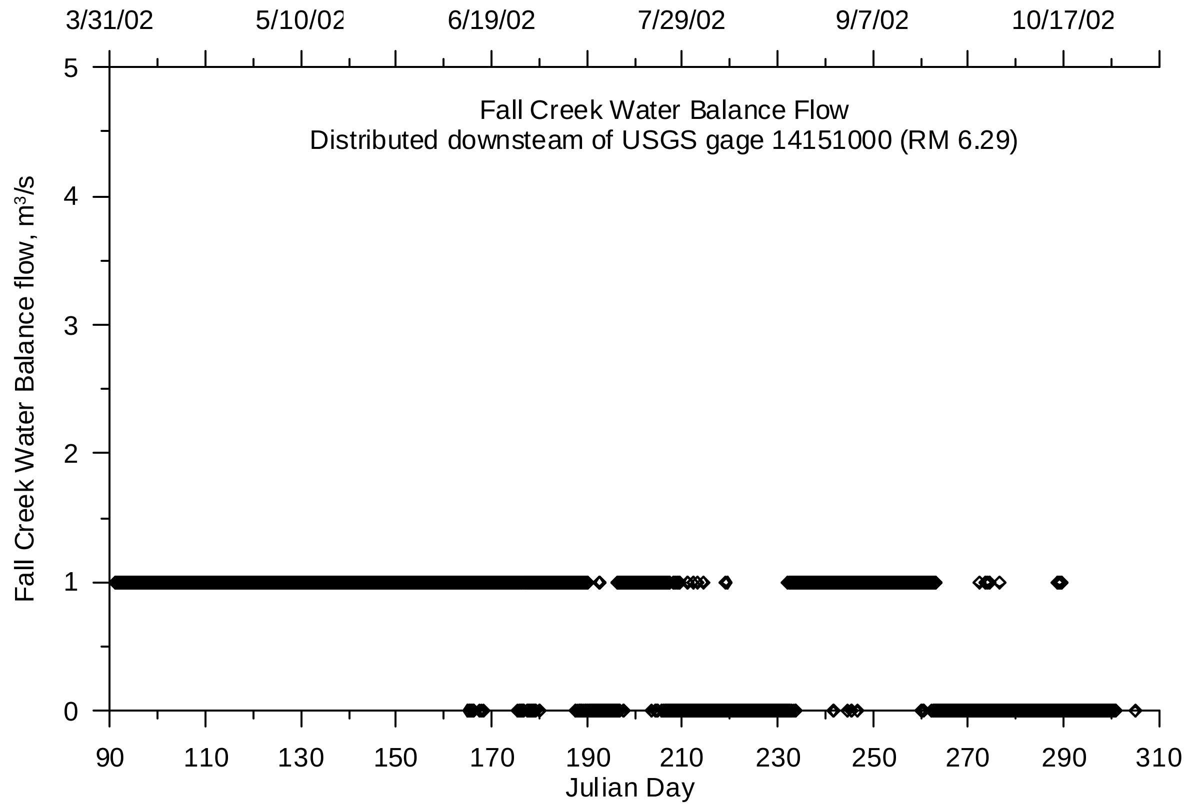

Figure 441: Middle Fork Willamette River water balance flow, 2002

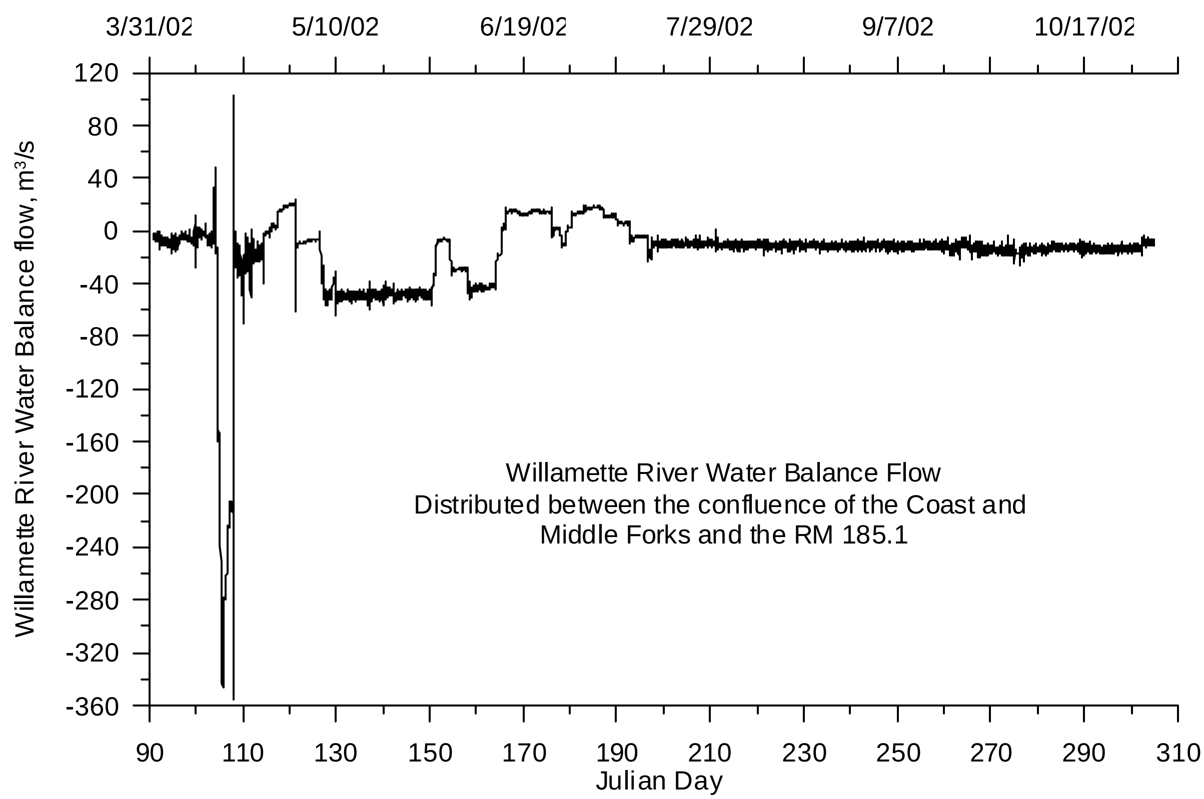

Figure 442: Willamette River water balance flow, 2002

Channel Widths

There were two types of data utilized for comparing with simulated stream widths. The first data set is comprised of channel widths collected by the U.S. Geological Survey as part of the three field surveys conducted in the spring and summer of 2002. The second data set consists of wetted channel widths identified from digital ortho-rectified aerial photographs associated with each 7.5 minute quadrangle map in a GIS database by the Oregon Department of Environmental Quality.

USGS Width Survey

In 2002 the U.S. Geological Survey conducted three field surveys of channel widths on the Coast Fork Willamette River, Middle Fork Willamette River, Fall Creek and Row River. Since there was limited bathymetric data to develop the model grid for these rivers the field survey widths provide an additional model calibration data set. The surveys were conducted on April 8-9, with higher stream flows, June 4-5, with lower flows, and August 6-7, when the flows would be at their summer lows. Figure 443 shows the location of the survey sites. Table 66 lists the survey sites, the river mile location, and corresponding survey dates. The model was run in 2002 for calibration so channel widths were output from the model corresponding to the survey data's date, time, and location.

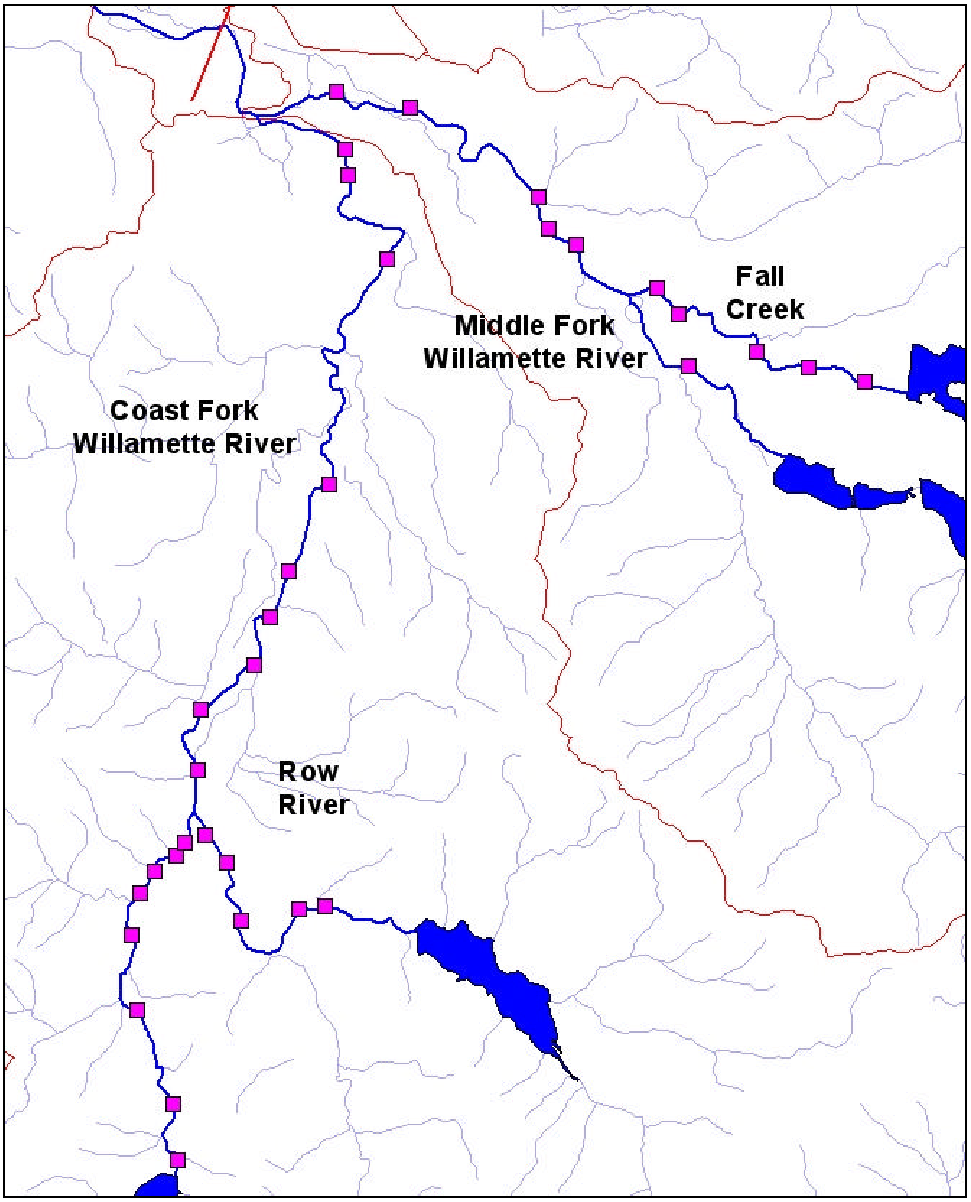

Figure 443: Coast Fork and Middle Fork Willamette River USGS width survey site locations

Table 66: Coast Fork and middle Fork Willamette River USGS width survey sites and dates

River	Site Name	River Mile	Model Segment	Date 1	Date 2	Date 3
Coast Fork	gaging station below Cottage Grove Lake	29.2	3	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Weyerhaeuser private road	28.0	12	04/08/2002	06/05/2002	08/06/2002
Coast Fork	London / Hillside Dr.	25.8	26	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Hwy 99/River Rd, Cottage Grove	23.9	38	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Main St., Cottage Grove	22.9	44	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Woodson Rd bridge, Cottage Grove	22.3	47	04/08/2002	06/05/2002	08/06/2002

River	Site Name	River Mile	Model Segment	Date 1	Date 2	Date 3
Coast Fork	Hwy 99 bridge, Cottage Grove	21.6	52	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Hwy 99, Saginaw	21.4	54	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Saginaw Rd East	20.0	63	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Walker	18.6	73	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Lynx Hollow (Davison Rd)	17.1	83	04/08/2002	06/05/2002	08/06/2002
Coast Fork	I-5 bridge (downstream side)	15.7	92	04/08/2002	06/05/2002	08/06/2002
Coast Fork	River Rd, Row Rd	14.5	99	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Cloverdale Rd near Cloverdale	12.5	112	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Hwy 58, west of Pleasant Hill	6.4	153	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Mt. Pisgaer arboretum	3.6	171	04/08/2002	06/05/2002	08/06/2002
Coast Fork	Seavey Way bridge	3.1	175	04/08/2002	06/05/2002	08/06/2002
Row River	Row River Rd gaging station	5.5	207	04/09/2002	06/05/2002	08/06/2002
Row River	Row River Rd near Bryson-Sears Rd	5.0	210	04/09/2002	06/05/2002	08/06/2002
Row River	Row River Road bridge	2.8	223	04/09/2002	06/05/2002	08/06/2002
Row River	Sears Road (east side of island)	1.5	235	04/09/2002	06/05/2002	08/06/2002
Row River	I-5 south	0.5	239	04/09/2002	06/05/2002	08/06/2002
Middle Fork	Pengra boat ramp	200.8	267	04/09/2002	06/04/2002	08/07/2002
Middle Fork	Jasper Rd, Jasper	196.5	295	04/09/2002	06/04/2002	08/07/2002
Middle Fork	Jasper State Park	195.7	299	04/09/2002	06/04/2002	08/07/2002
Middle Fork	Parkway bridge, Jasper	195	304	04/09/2002	06/04/2002	08/07/2002
Middle Fork	Clearwater boat ramp	191.2	330	04/09/2002	06/04/2002	08/07/2002
Middle Fork	sub water dept, Springfield	189.2	342	04/09/2002	06/04/2002	08/07/2002
Fall Creek	Unity bridge, Unity	6.1	363	04/09/2002	06/04/2002	08/07/2002
Fall Creek	Fall Creek Park	4.8	371	04/09/2002	06/04/2002	08/07/2002
Fall Creek	Place Rd near Unity	3.6	379	04/09/2002	06/04/2002	08/07/2002
Fall Creek	Jasper Rd bridge at Lowell Rd	1.2	395	04/09/2002	06/04/2002	08/07/2002
Fall Creek	Jasper Rd	0.5	399	04/09/2002	06/04/2002	08/07/2002

Figure 444, Figure 445, and Figure 446 show plots comparing the channel widths for the Coast Fork Willamette River on April 8, June 5, and August 6, 2002. All three figures show relatively close agreement between the survey widths and the model simulated wetted widths. The three furthest downstream sites (upstream is on the left and increasing model segments moving downstream to the right) have the largest disagreement between the model and data. The disagreement at these sites may be due to uncertainties in the channel bathymetry.

Figure 447, Figure 448, and Figure 449 show plots comparing the channel widths for the Row River on April 9, June 5, and August 6, 2002. The plots for all three dates show close agreement between the model and data at each of the sites.

Figure 450, Figure 451, and Figure 452 show plots comparing the channel widths for the Middle Fork Willamette River on April 9, June 4, and August 7, 2002. The plots show there is close model-data agreement along the Middle Fork Willamette River for the varying flows from spring into late summer.

Figure 453, Figure 454, and Figure 455 show plots comparing the channel widths for Fall Creek on April 9, June 4, and August 7, 2002. The first two figures show there is relatively close agreement between the model and data for April and June. The third figure shows larger discrepancies between the model and data, which are likely due to uncertainties in the river channel bathymetry. Improved bathymetric data may improve the simulated widths over the changes in flow, especially during the lower flows seen in late summer.

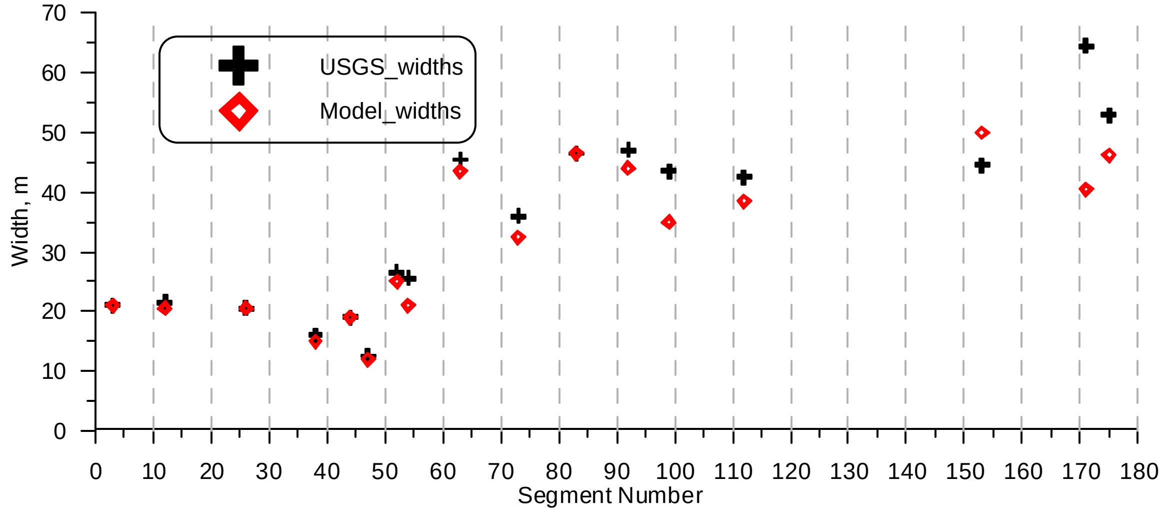

Figure 444: Coast Fork Willamette River USGS and model wetted width comparison on April 8, 2002

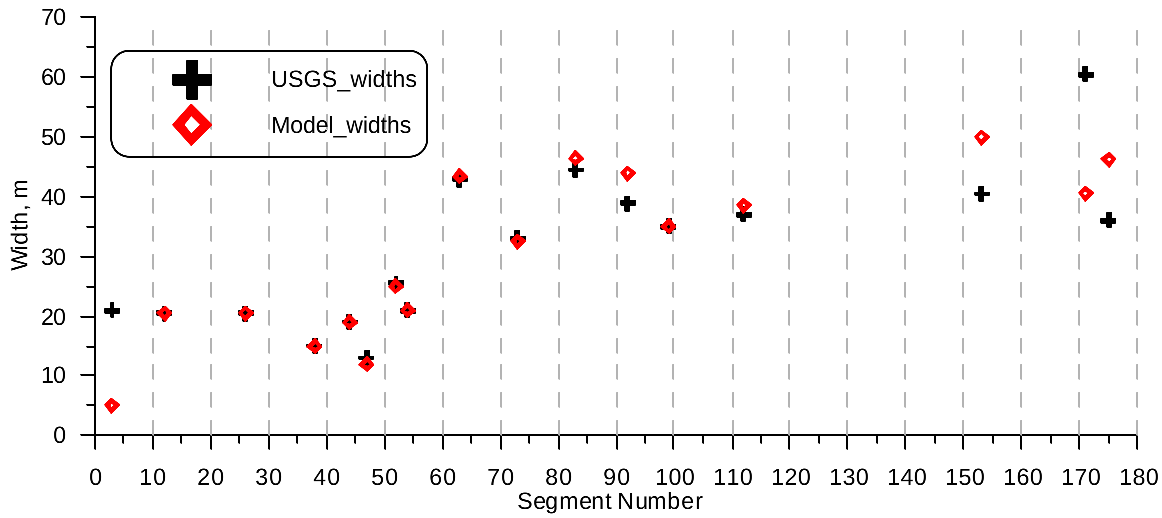

Figure 445: Coast Fork Willamette River USGS and model wetted width comparison on June 5, 2002

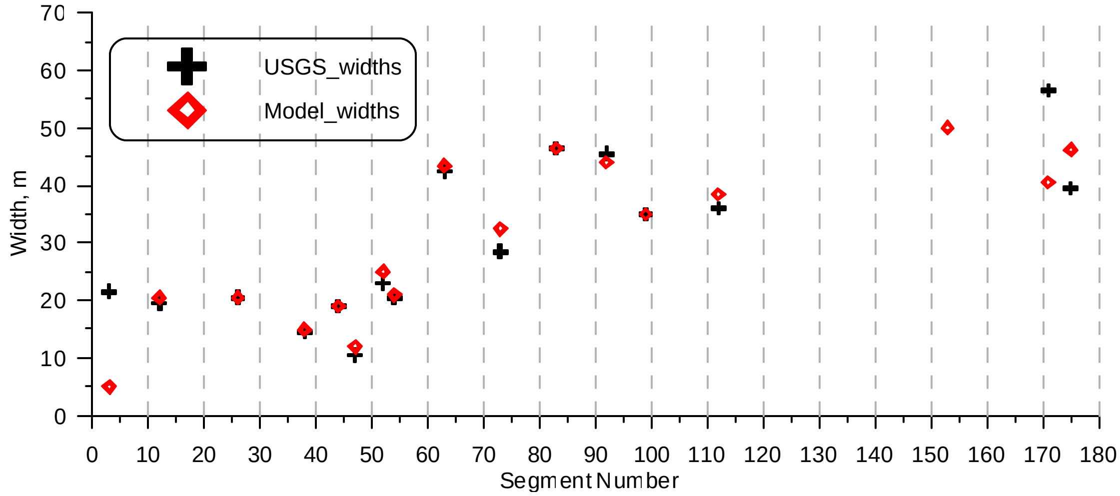

Figure 446: Coast Fork Willamette River USGS and model wetted width comparison on August 6, 2002

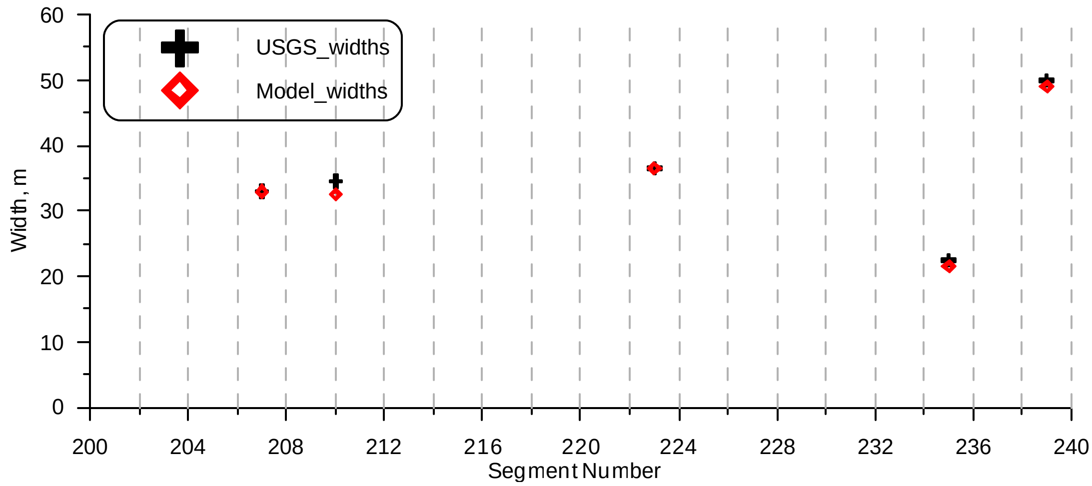

Figure 447: Row River USGS and model wetted width comparison on April 9 2002

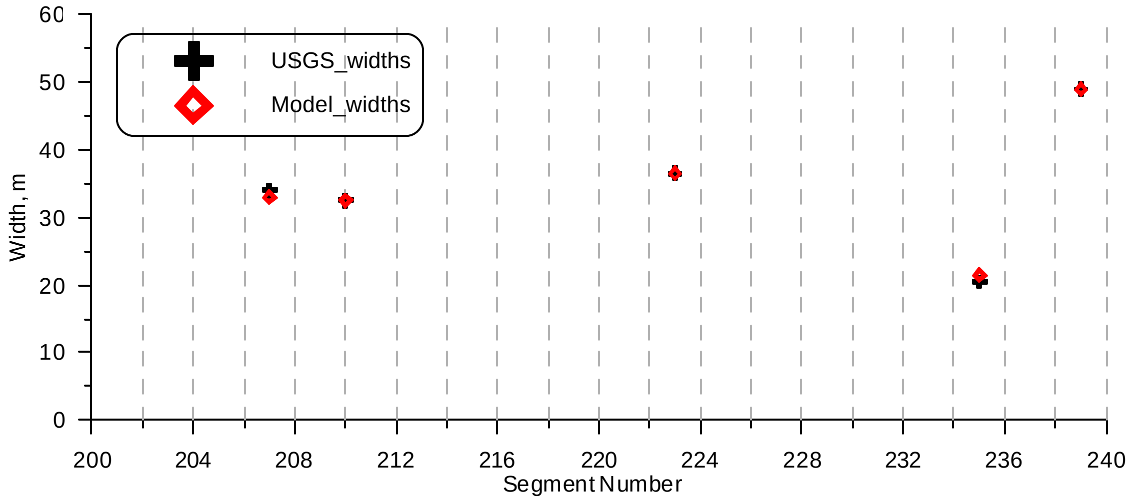

Figure 448: Row River USGS and model wetted width comparison on June 5, 2002

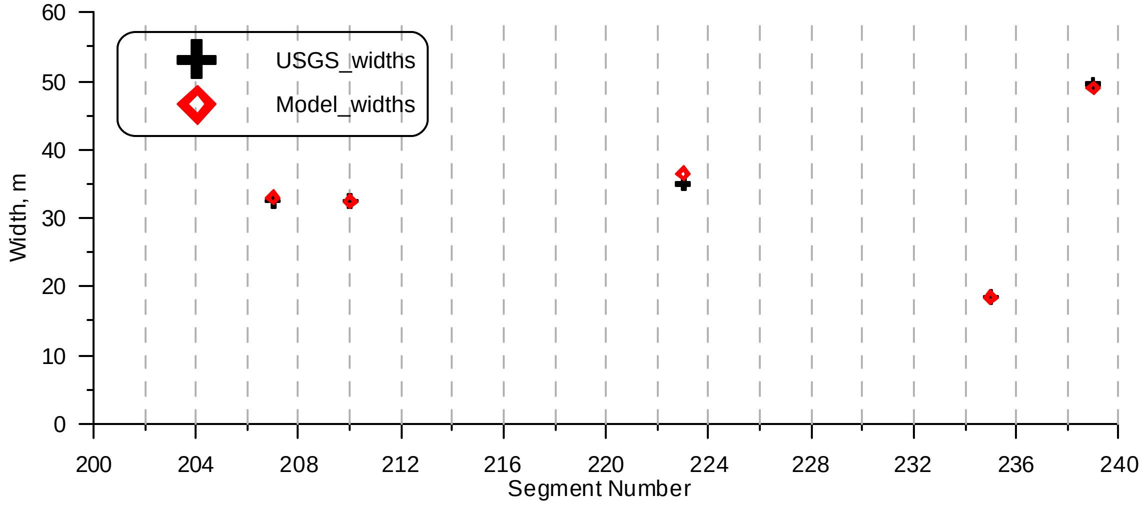

Figure 449: Row River USGS and model wetted width comparison on August 6, 2002

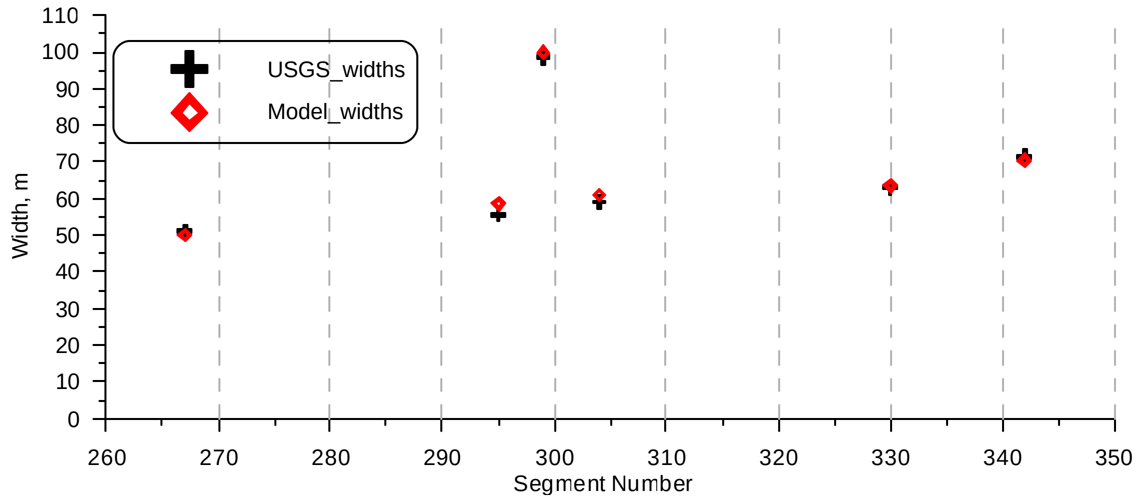

Figure 450: Middle Fork Willamette River USGS and model wetted width comparison on April 9, 2002

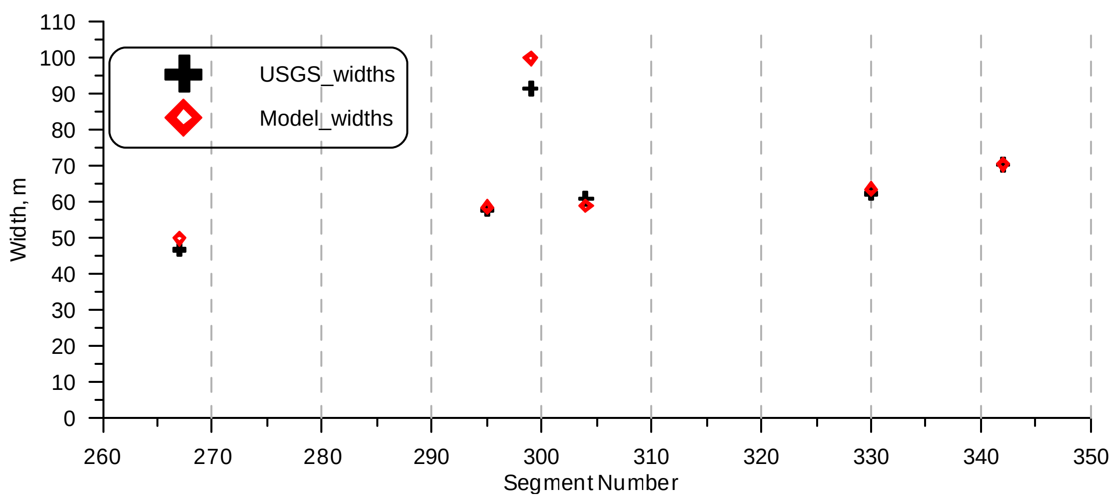

Figure 451: Middle Fork Willamette River USGS and model wetted width comparison on June 4, 2002

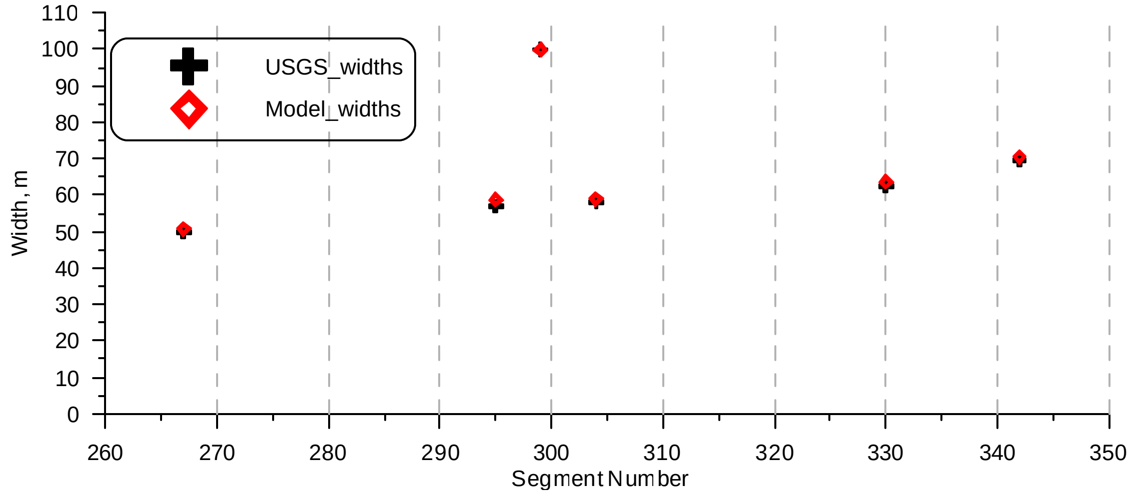

Figure 452: Middle Fork Willamette River USGS and model wetted width comparison on August 7, 2002

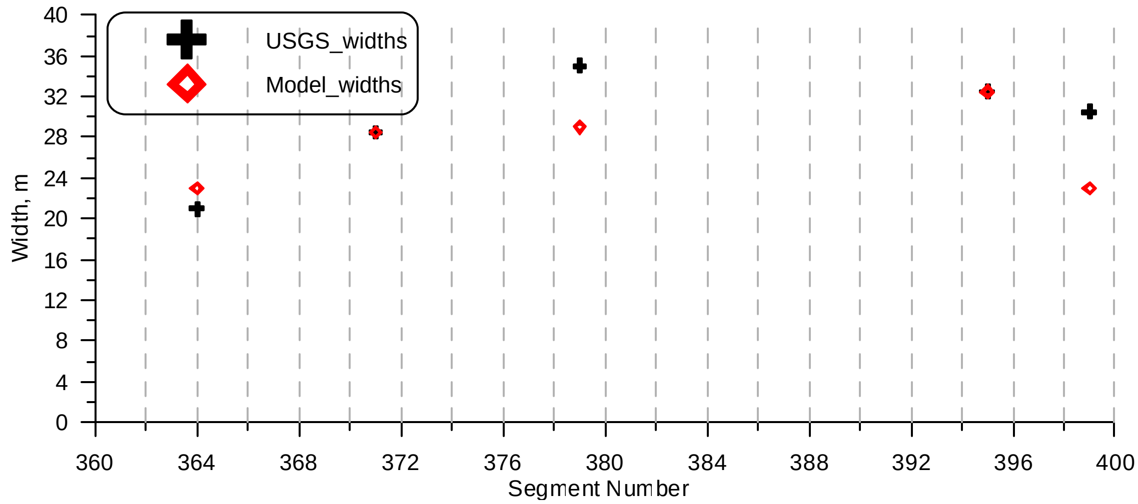

Figure 453: Fall Creek USGS and model wetted width comparison on April 9, 2002

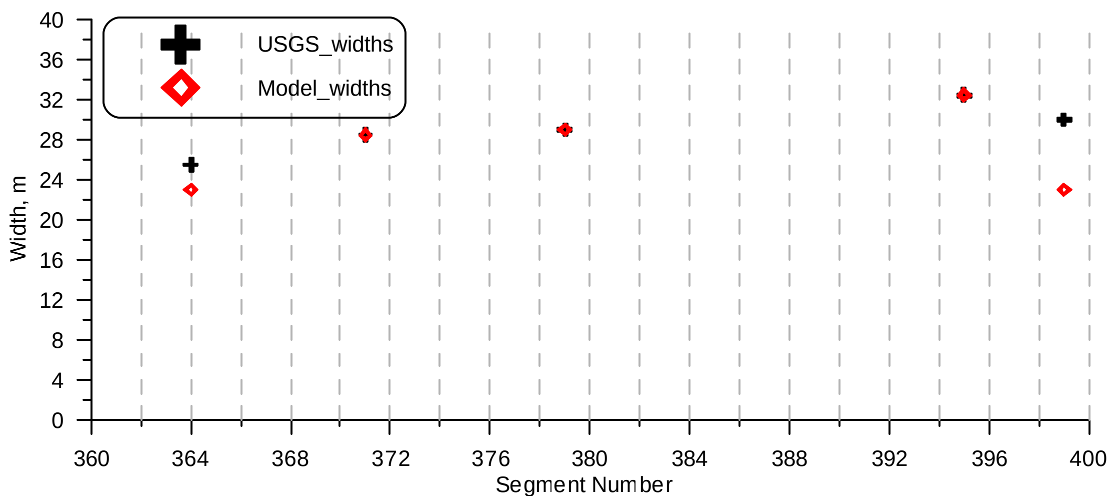

Figure 454: Fall Creek USGS and model wetted width comparison on June 4, 2002

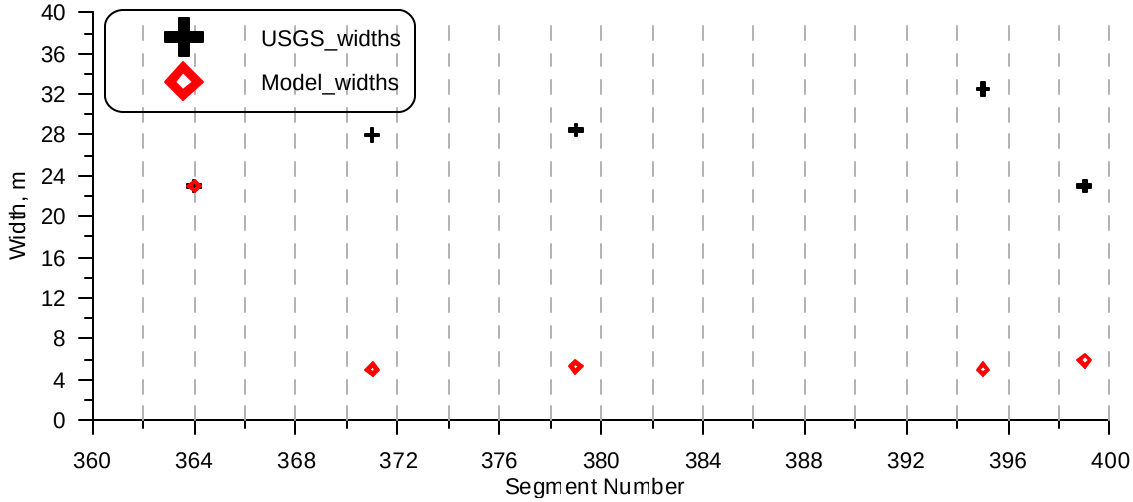

Figure 455: Fall Creek USGS and model wetted width comparison on August 7, 2002

DEQ Wetted Widths

The other channel width data set consists of wetted channel widths identified from digital ortho-rectified aerial photographs associated with individual 7.5 minute quadrangle maps. Oregon Department of Environmental Quality used the photographs in a GIS database to digitize the channel widths from the photos. The dates when the photos were taken was then put in a database and provided with the digitized widths. The dates of the aerial photos and their spatial range were used to identify the reaches along the river which were associated with each photos and corresponding date. Then the nearest USGS gage station was used to get the daily averaged flow in the river that corresponds with the photo. The model was run at each flow level for a specific period of time to allow steady state conditions and then the channel widths at the model segments corresponding to the each reach with photos was output from the model and compared with digitized data. The resolution of the digitized data corresponds to every 30.5 meters along the river channel and the model output is at a resolution of every 250 m.

Figure 456 shows a plot comparing the digitized channel widths with the model output results for the Coast Fork Willamette River. The plot shows the digitized data is highly variable and the model results change less dramatically from segment to segment. The figure shows there are stretches of the river where the model results are close to the digitized data. The region from model segment number 2 to 50 indicates the model is under predicting the channel widths. Overall, there is relatively good agreement. Thee uncertainties in the channel bathymetry used to develop the model grid which could cause errors in the predicted channel widths. The digitized channel widths were based on photos from 1994 and 1995 so there may have been some changes in the channel bathymetry since then. Lastly, adjustments to the channel bathymetry to match this digitized have to weighed with the USGS width survey conducted, the hydrodynamic data collected and the temperature data used to calibrate the model.

Figure 457 shows a plot comparing the digitized channel widths with the model output results for Row River. The figure shows there is some agreement between the model and data but for most of the river channel there are some discrepancies. The difference between the model and data can be attributed the lack of bathymetric data for the river channel.

Figure 458 shows a plot comparing the digitized channel widths with the model output results for the Middle Fork Willamette River. The figure indicates there is relatively good agreement between the model and the data.

Figure 459 shows a plot comparing the digitized channel widths with the model output results for Fall Creek. Similar to Row River the figure for Fall Creek indicates there are some width differences between the model and data. More detailed bathymetric data might help reduce some the discrepancies between the model and data.

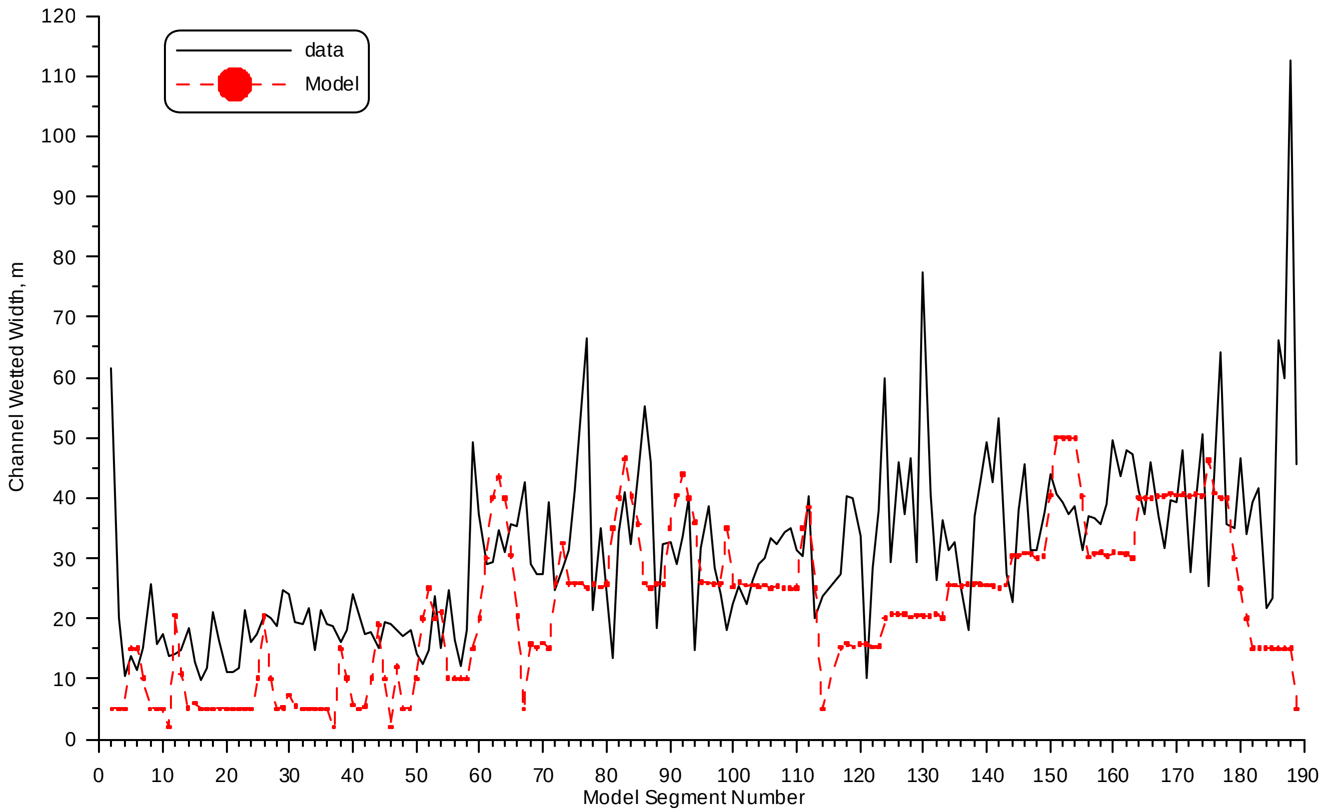

Figure 456: Coast Fork Willamette River wetted width comparison between model and GIS data set

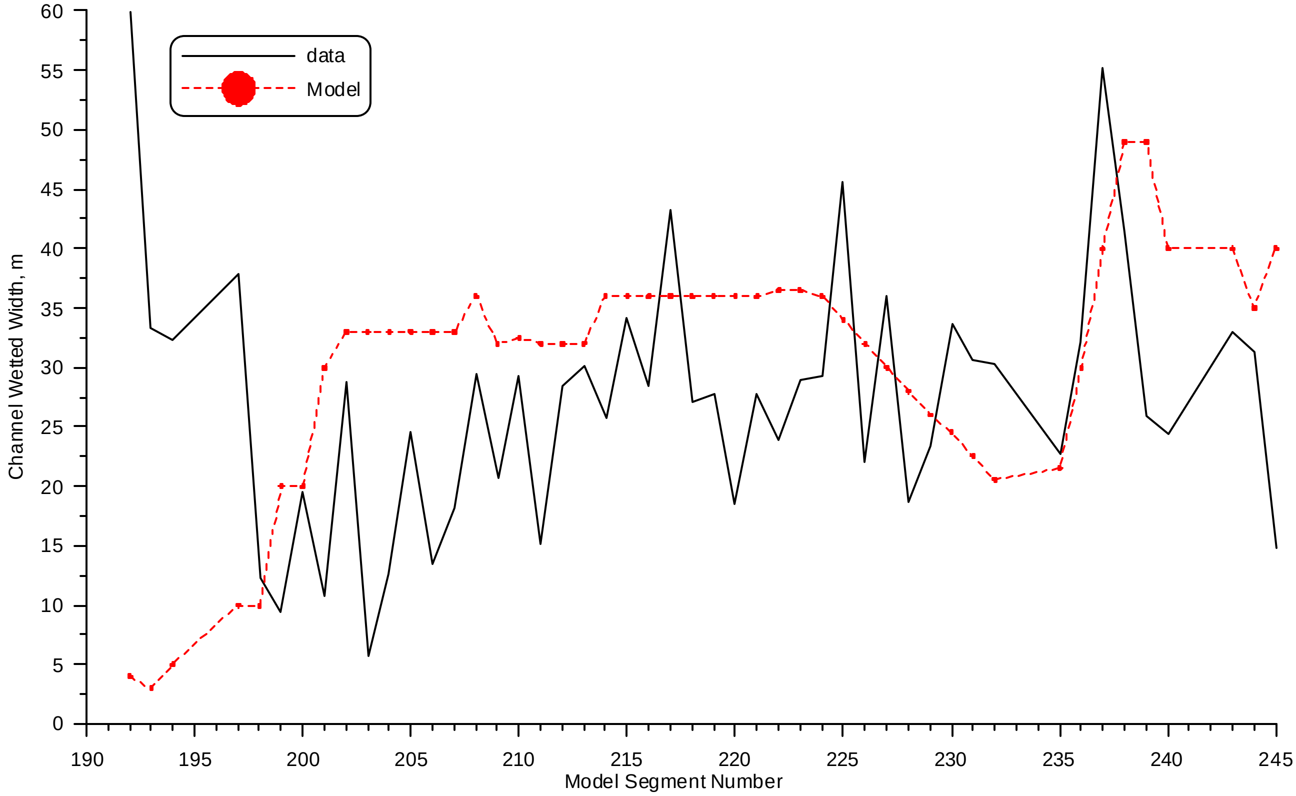

Figure 457: Row River wetted width comparison between model and GIS data set

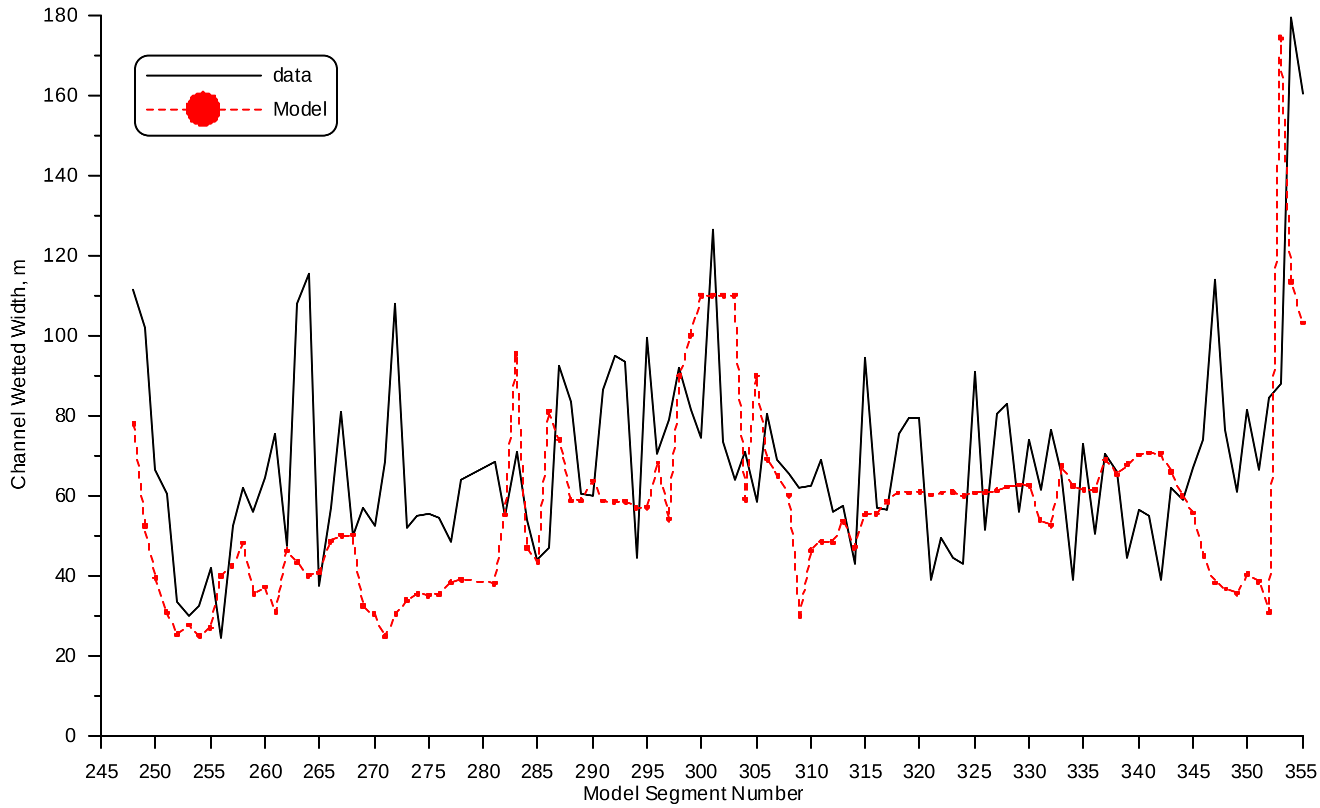

Figure 458: Middle Fork Willamette River wetted width comparison between model and GIS data set

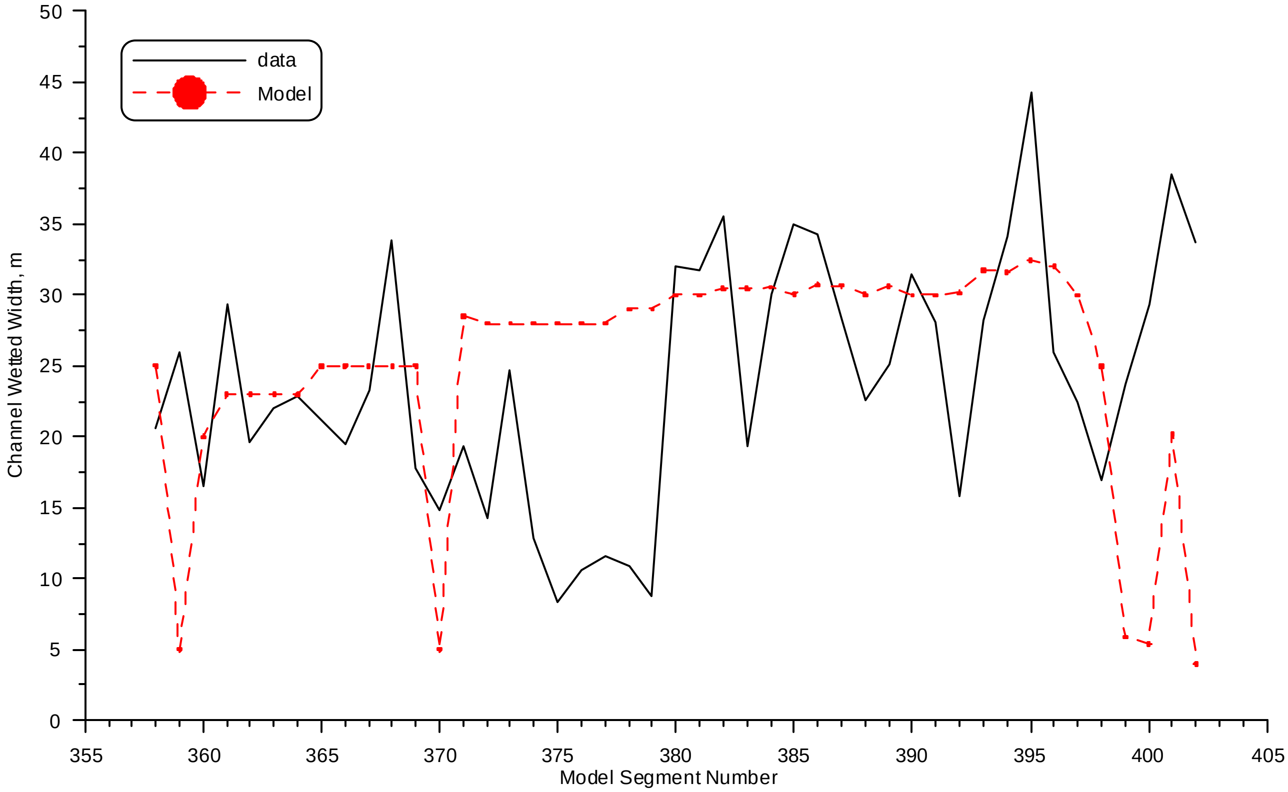

Figure 459: Fall Creek wetted width comparison between model and GIS data set

Time of Travel/Dye Studies

During the 1960's the U.S. Geological Survey conducted extensive travel rate vs. discharge studies (Harris, 1968; Appendix B, Annear et al, 2004a) The Harris, 1968 study examined time of travel for varied flows over the Coast Fork Middle Fork domain area. Table 67 lists the study reaches along the Coast Fork Willamette River and provides the model segments associated with the ends of each reach. Table 68 lists the study reaches along the Middle Fork Willamette River and provides the model segments associated with the ends of each reach. The RM locations provided in each table are related to those presented elsewhere in this report and differ slightly from the river mile reported in Harris, 1968. It is uncertain how much the channel morphology and travel rates may have changed between the studies conducted in 1962-63 and the model calibration periods of 2001 and 2002.

A total of seven different flow rates were used on the Coast Fork Willamette River to estimate travel rates for the six reaches. Within each reach two or three flows rates were used to estimate travel rates. Figure 460 shows plots for reaches one through four with the travel rates within each reach plotted vs. flow. The figure indicates there is relatively good agreement between the model and the travel time study data. Figure 461 shows travel rate vs. flow plots for reaches five and six and indicates there is some agreement between the model and data. Both figures show some discrepancies between the model and data, which may be attributable to changes in stream channel bathymetry since the study was conducted in 1962-63.

Three different flow rates were used on the Middle Fork Willamette River to estimate travel rates within the one study reach identified in Table 68. Figure 462 shows a travel rate vs. flow plot for the one reaches and indicates there is good agreement between the model and data.

Table 67: Coast Fork Willamette River 1968 time of travel reaches, (Harris, 1968)

Reach	Upstream End	Up-stream RM	Model Segment	Downstream End	Down-stream RM	Model Segment
1	Gaging Station 1535	29.4	4	Highway 231 bridge	23.9	38
2	Highway 231 bridge	23.9	38	Row River	20.7	58
3	Row River	20.7	58	Interstate 5 bridge	15.7	90
4	Interstate 5 bridge	15.7	90	Cloverdale bridge	12.8	108
5	Cloverdale bridge	12.8	108	Highway 58 bridge	6.4	149
6	Highway 58 bridge	6.4	149	mouth	0.0	189

Table 68: Middle Fork Willamette River 1968 time of travel reaches, (Harris, 1968)

Reach	Upstream End	Up-stream RM	Model Segment	Downstream End	Down-stream RM	Model Segment
1	Dexter Dam	203.7	248	Coast Fork Willamette River	187.0	355

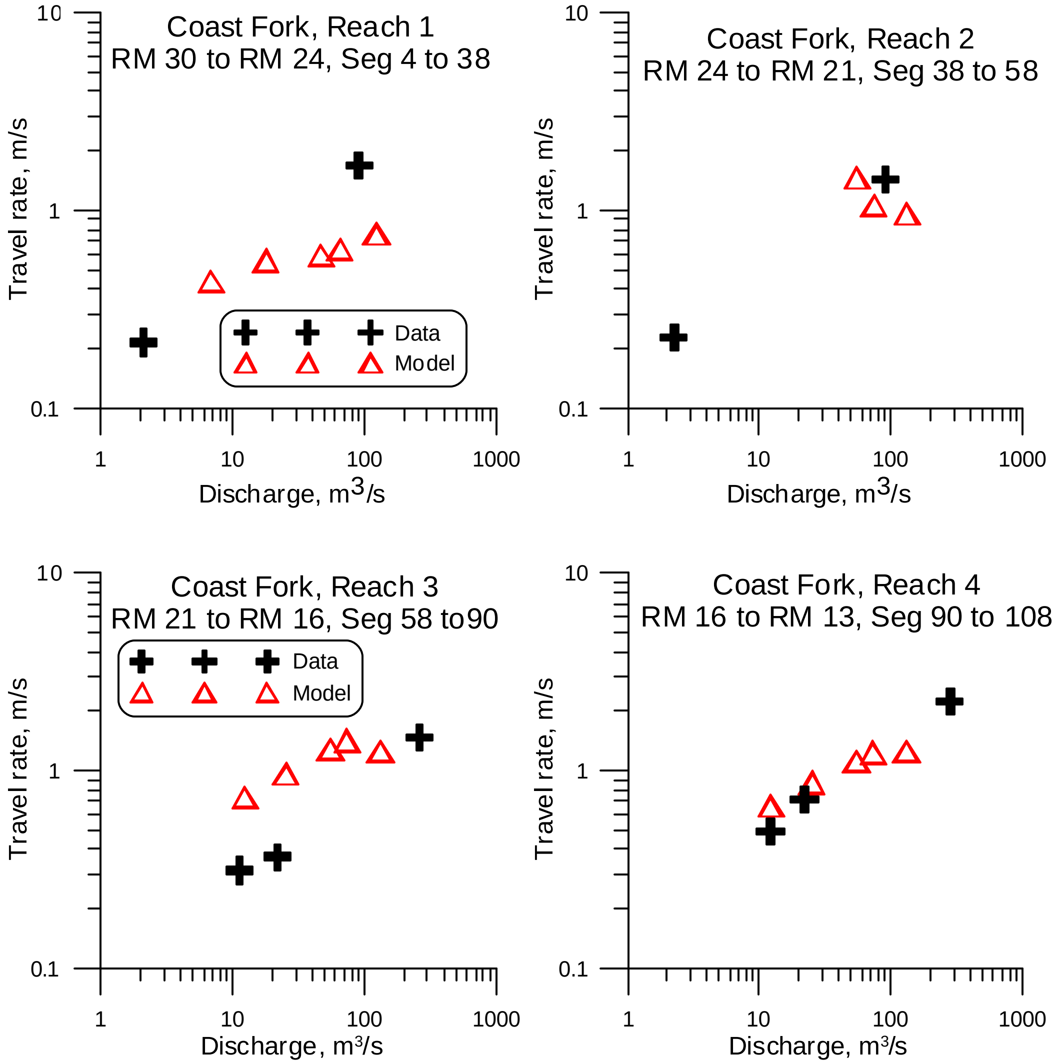

Figure 460: Time of travel study on the Coast Fork Willamette River, Reaches 1 to 4 (Harris, 1968)

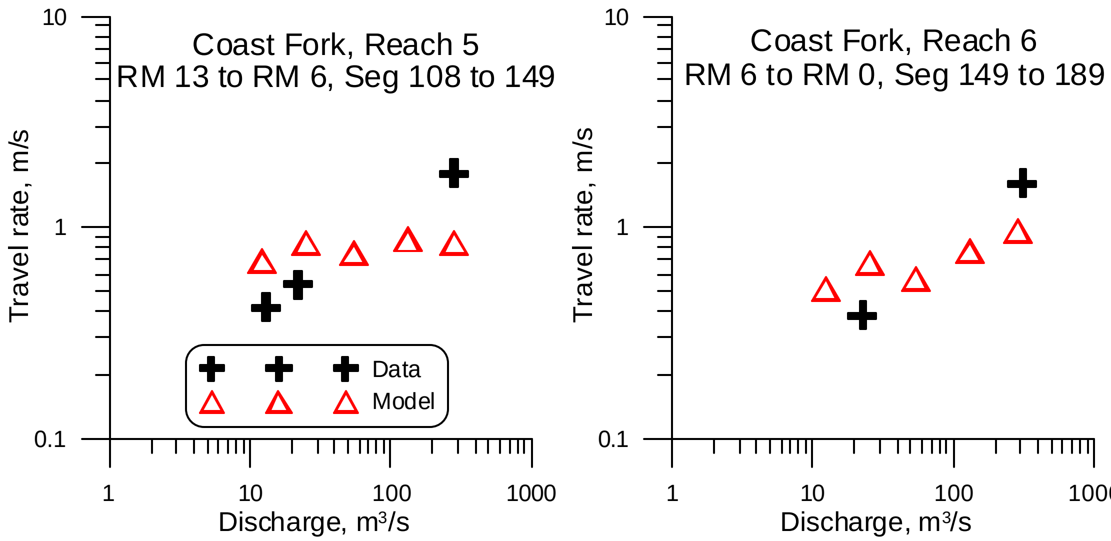

Figure 461: Time of travel study on the Coast Fork Willamette River, Reaches 5 and 6 (Harris, 1968)

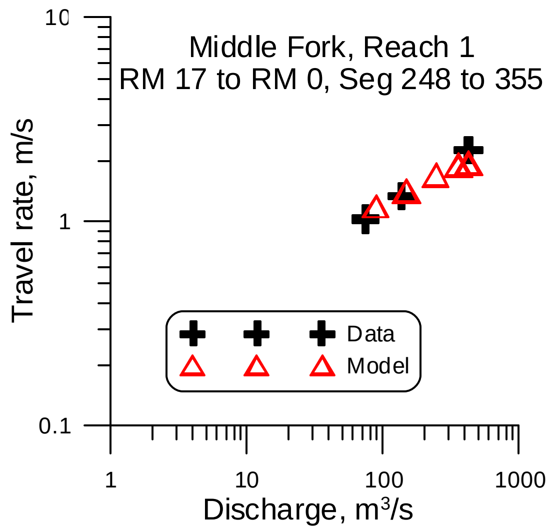

Figure 462: Time of travel study on the Middle Fork Willamette River, Reach 1 (Harris, 1968)

Water Temperature

Water temperature was calibrated using continuous temperature data recorded every half hour or hour at several locations in the basins. Model-data comparisons were made both at small time scales and at larger time scales over the simulation period to ensure diurnal fluctuations were simulated accurately. Calibration parameters included: the Manning's friction factor, channel widths, wind sheltering, evaporation, meteorological data sets, and sediment temperatures. Vegetative and topographic shade characteristics were not adjusted since the model input was developed using a detailed GIS analysis.

The Coast Fork and Middle Fork Willamette River basin model has twelve sites where continuous temperatures were recorded for calibrating the model. Figure 463 shows a map of the basins with the gage site locations and Table 69 shows a list of the gage sites with RM and corresponding model segment information.

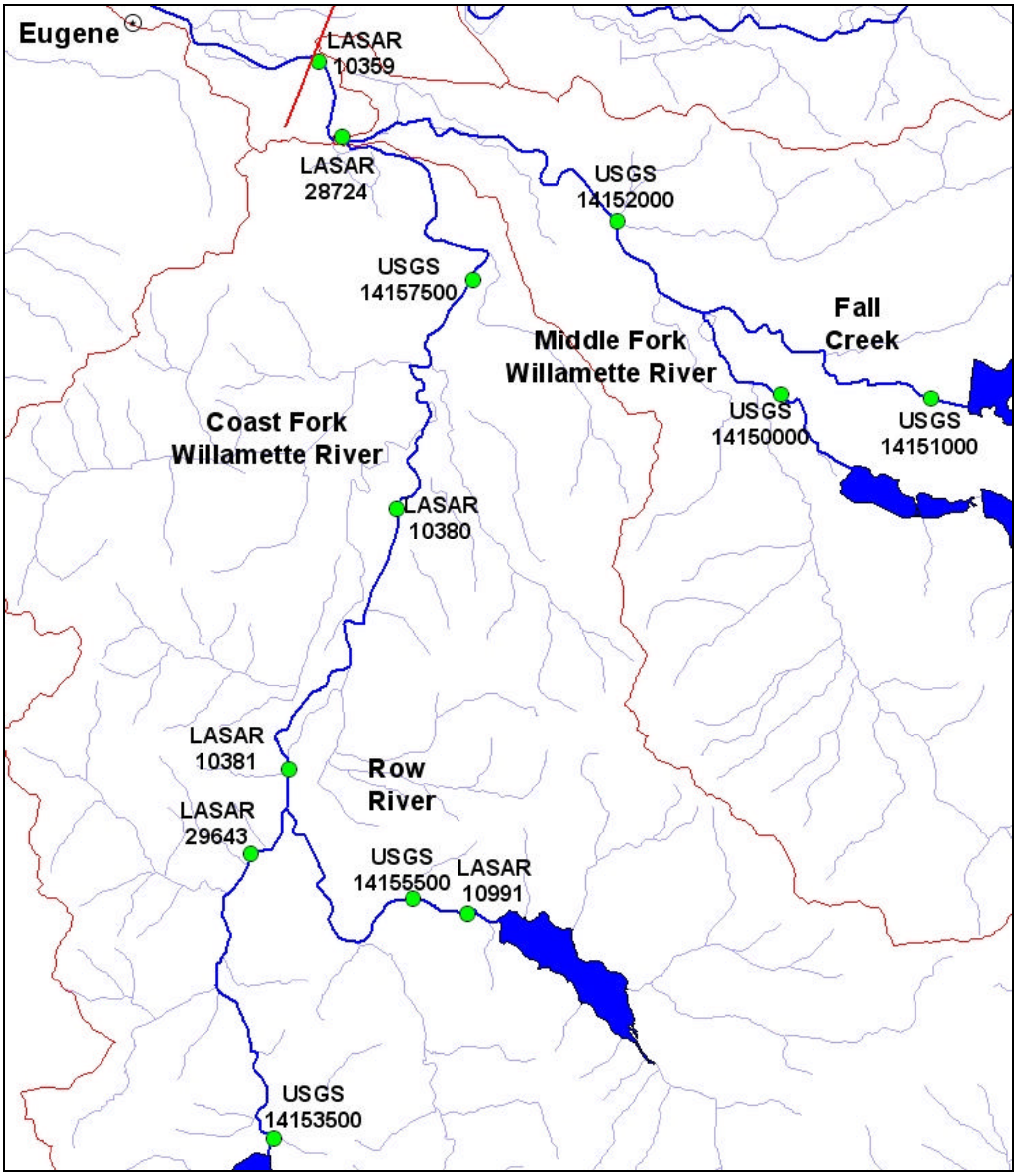

Figure 463: Coast Fork and Middle Fork Willamette River temperature calibration site locations

Table 69: Coast Fork and Middle Fork Willamette River temperature calibration sites

Site ID	Site Description	RM	Model Segment
USGS 14153500	Coast Fork below Cottage Grove Dam (u/s Row River)	28.69	4
LASAR 29643	Coast Fork Willamette River above Cottage Grove STP (u/s Row River)	21.60	49
LASAR 10381	Coast Fork Willamette River at Saginaw Bridge (d/s Row River)	19.34	63
LASAR 10380	Coast Fork Willamette River at Creswell (d/s Row River)	12.27	109
USGS 14157500	Coast Fork Willamette River near Goshen (d/s Row River)	5.72	153
LASAR 10991	Row River below Dorena Reservoir	6.74	199
USGS 14155500	Row River near Cottage Grove	5.51	206
USGS 14150000	Middle Fork Willamette River near Dexter (u/s Fall Creek)	13.95	264

Site ID	Site Description	RM	Model Segment
USGS 14152000	Middle Fork Willamette River at Jasper (d/s Fall Creek)	8.15	303
LASAR 28724	Middle Fork Willamette River near mouth #1	0.29	353
USGS 14151000	Fall Creek below Winberry Creek near Fall Creek	6.29	363
LASAR 10359	Willamette River at Hwy 126 (Springfield)	185.08	416

The model was calibrated by comparing the continuous temperature data and model results. The model will be used for running scenarios examining the daily maximum temperature so model-data comparisons were done for the daily maximum temperature as well.

Continuous Temperatures

Year 2001

Temperatures on the Coast Fork and Middle Fork Willamette River were calibrated from April to October 2001. Table 70 lists the model-data error statistics for continuous temperature model results and data. The table shows absolute mean errors (AME) of less than 1 ^oC and root mean square error (RMS) of less than 1.22 ^oC for most sites. The exceptions are two sites on the Coast Fork Willamette River where AME and RMS errors are less than 1.6 ^oC and 1.9 ^oC, respectively. Overall the mean error shows there is slight bias on the cooler side of about 0.3 ^oC.

Figure 464 shows a model-data temperature comparison on the Coast Fork Willamette River below the model upstream boundary condition. Since the site is so close to the upstream boundary the model-data comparison is expected to be close as demonstrated by the error statistics of 0.10 ^oC. The next downstream site at RM 19.3, at Saginaw Bridge, as shown in Figure 465, indicates there is some model-data agreement but the model results show diurnal temperature swings which are too large compared with data. This may be due to uncertainties in the river channel bathymetry, which may be currently overestimating the channel width.

Figure 466 shows a model-data temperature comparison on the Coast Fork Willamette River at Creswell, OR (RM 12.3). The model-data temperature comparison shows similar results to the site upstream with the model showing too large of diurnal temperature swings. This results in one of the sites with model-data error statistics over 1^o C.

Figure 467 shows a model-data continuous temperature comparison on the Coast Fork Willamette River at RM 5.7, which is near Goshen, OR. This figure shows there is much less temperature data available at this site than the other sites compared with model results. The model results tend to show larger diurnal temperature swings than the data and are too cool through mid-September but match well with data from mid-September through the end of October. This is one of the other sites with model-data error statistics above 1 ^oC.

Figure 468 shows a plot of a model-data continuous temperature comparison on Row River at RM 5.5. The upstream boundary condition on Row River is at RM 7.5 so the monitoring site is only 2 mile downstream and the results are therefore expected to match reasonably well. The figure indicates there is good agreement between the model and data with model showing slightly larger diurnal temperature swings than the data.

Figure 469 shows a plot of model-data temperature time series comparison on the Middle Fork Willamette River at RM 14, which is 2.5 miles downstream from the upstream boundary condition. The figure indicates there is good agreement between the model and data, though there is limited data at this site compared to downstream locations.

Continuous temperature model results were compared with data on the Middle Fork Willamette River downstream of the confluence with Fall Creek at RM 8.2, as shown in Figure 470. For this site on the river there was continuous temperature data over the whole simulation period and the model results are shown to match the data well.

Figure 471 shows a plot comparing the continuous temperature model results with data on the Middle Fork Willamette River just upstream of the confluence with the Coast Fork Willamette River. The figure shows there is good model-data agreement through the simulation period.

There was only one continuous temperature monitoring site on Fall Creek, located at RM 6.3, which is only 0.8 miles downstream from the upstream boundary condition. The data set was limited to the end of July through the end of October in 2001. The figure shows there is good agreement the model and data as expected.

The furthest downstream location in the model corresponds to the RM 185.1 on the main stem of the Willamette River where highway 126 crosses the river. Figure 473 shows a plot of a model-data continuous temperature comparison, and indicates there is good model-data agreement with the model having slightly larger diurnal temperature swings periodically.

Table 70: Coast and Middle Fork Willamette River continuous water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
USGS 14153500	28.69	4	4341	-0.02	0.08	0.10
LASAR 29643	21.60	49	No data			
LASAR 10381	19.34	63	7461	-0.48	0.99	1.21
LASAR 10380	12.27	109	7459	-1.34	1.43	1.74
USGS 14157500	5.72	153	3714	-1.49	1.52	1.87
LASAR 10991	6.74	199	No data			
USGS 14155500	5.51	206	4396	0.25	0.48	0.85
USGS 14150000	13.95	264	4434	-0.03	0.16	0.20
USGS 14152000	8.15	303	10082	0.25	0.39	0.52
LASAR 28724	0.29	353	4162	-0.06	0.38	0.50
USGS 14151000	6.29	363	4393	0.07	0.23	0.31
LASAR 10359	185.08	416	7419	-0.36	0.52	0.63

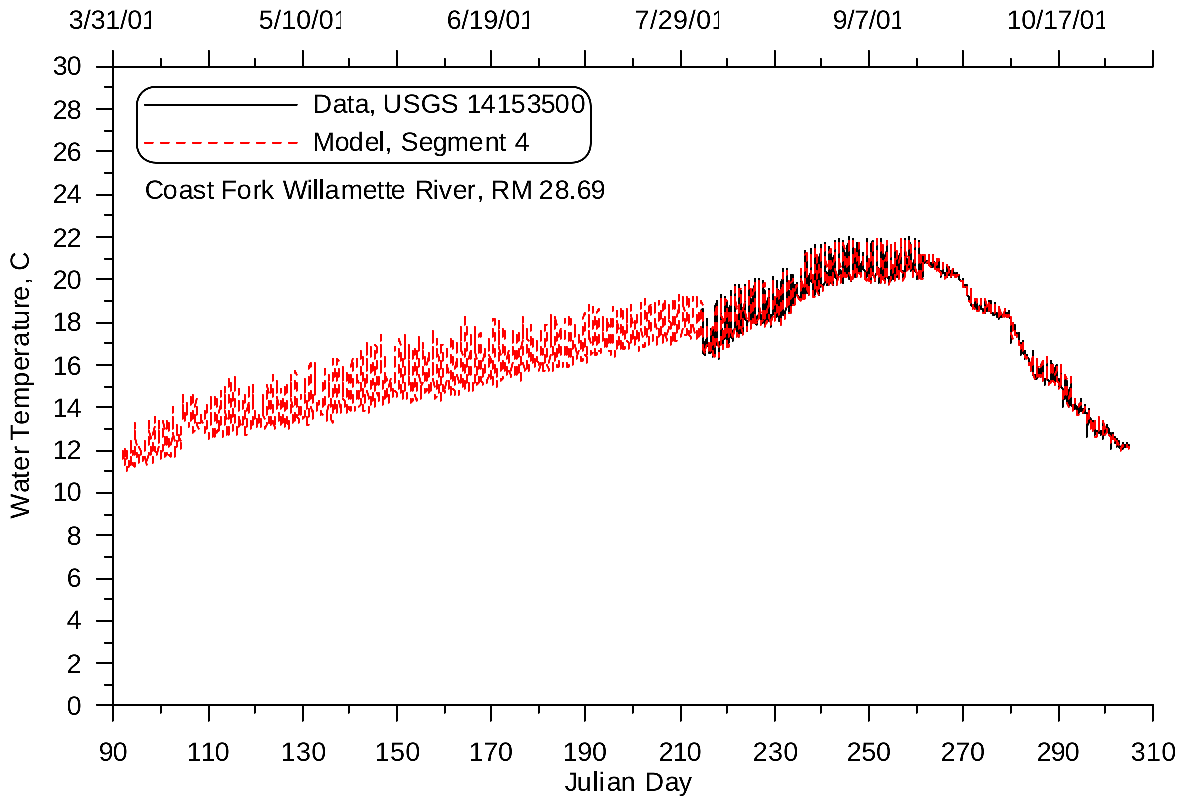

Figure 464: Coast Fork Willamette River below Cottage Grove Dam model-data continuous temperature comparison, 2001

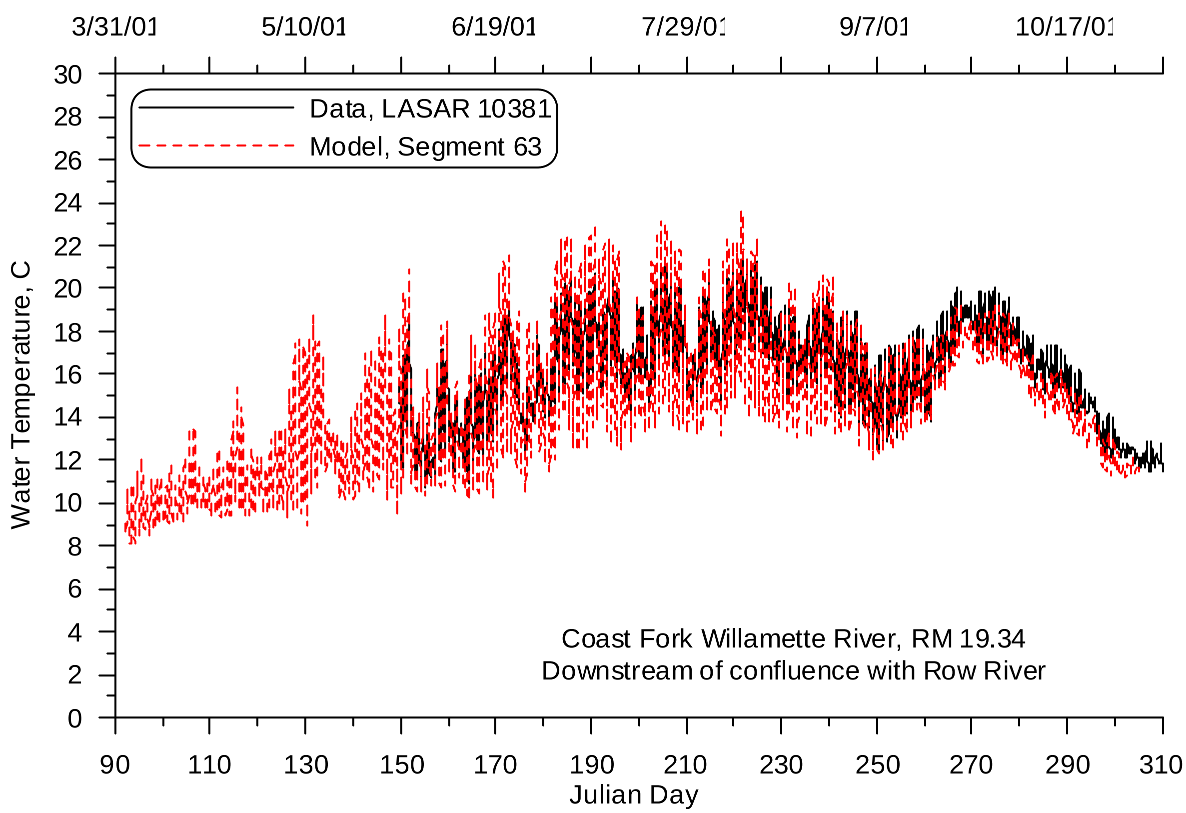

Figure 465: Coast Fork Willamette River at Saginaw Bridge model-data continuous temperature comparison, 2001

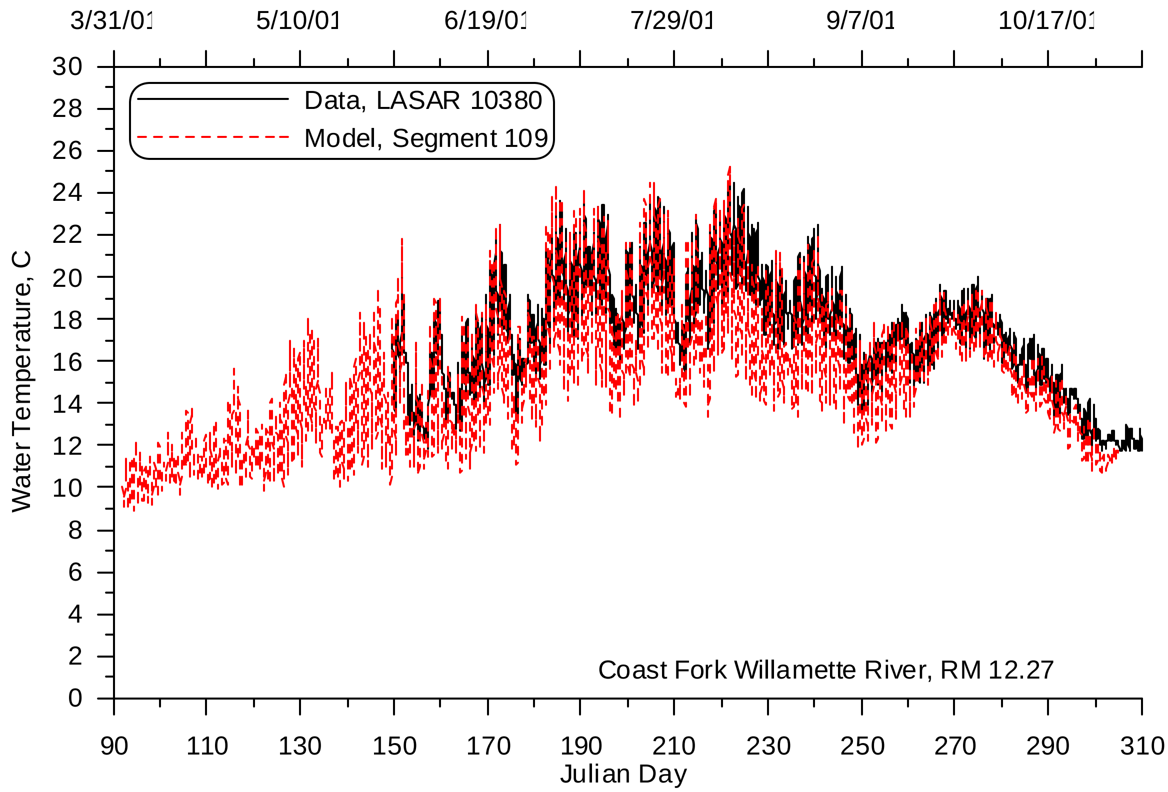

Figure 466: Coast Fork Willamette River at Creswell model-data continuous temperature comparison, 2001

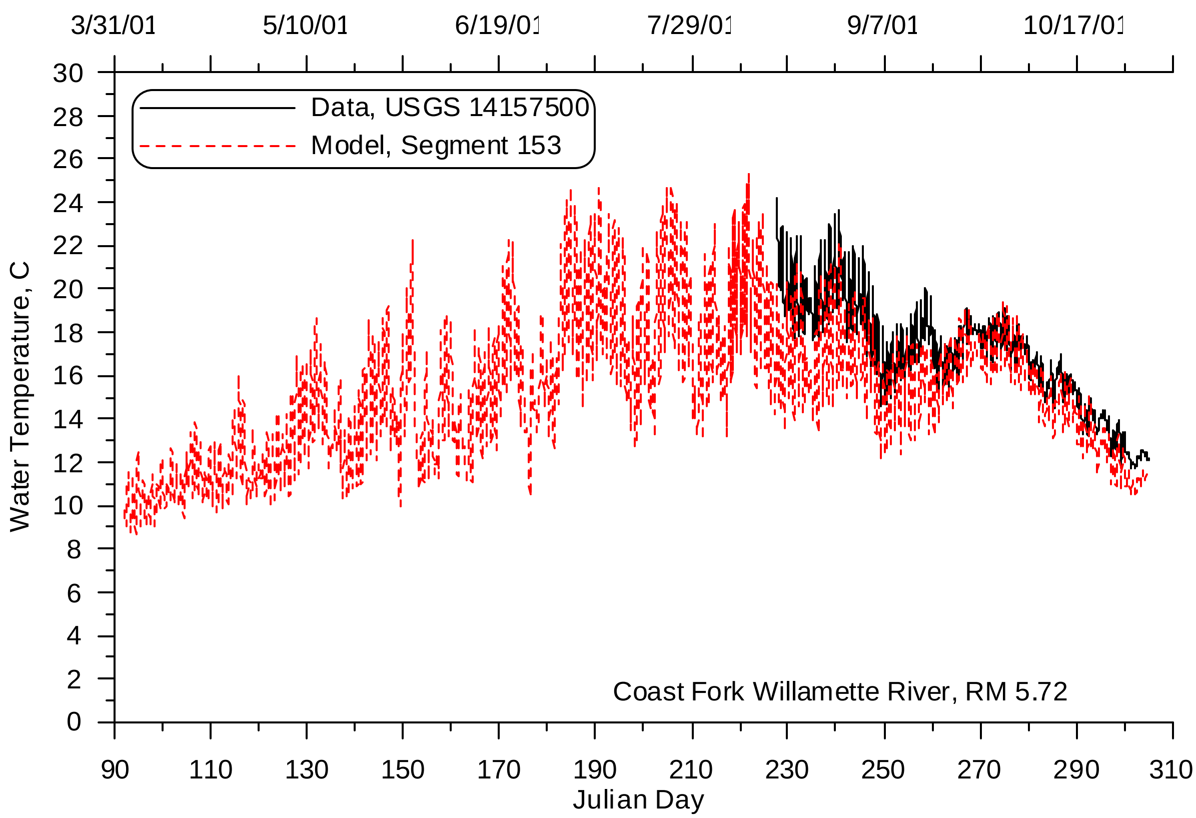

Figure 467: Coast Fork Willamette River near Goshen model-data continuous temperature comparison, 2001

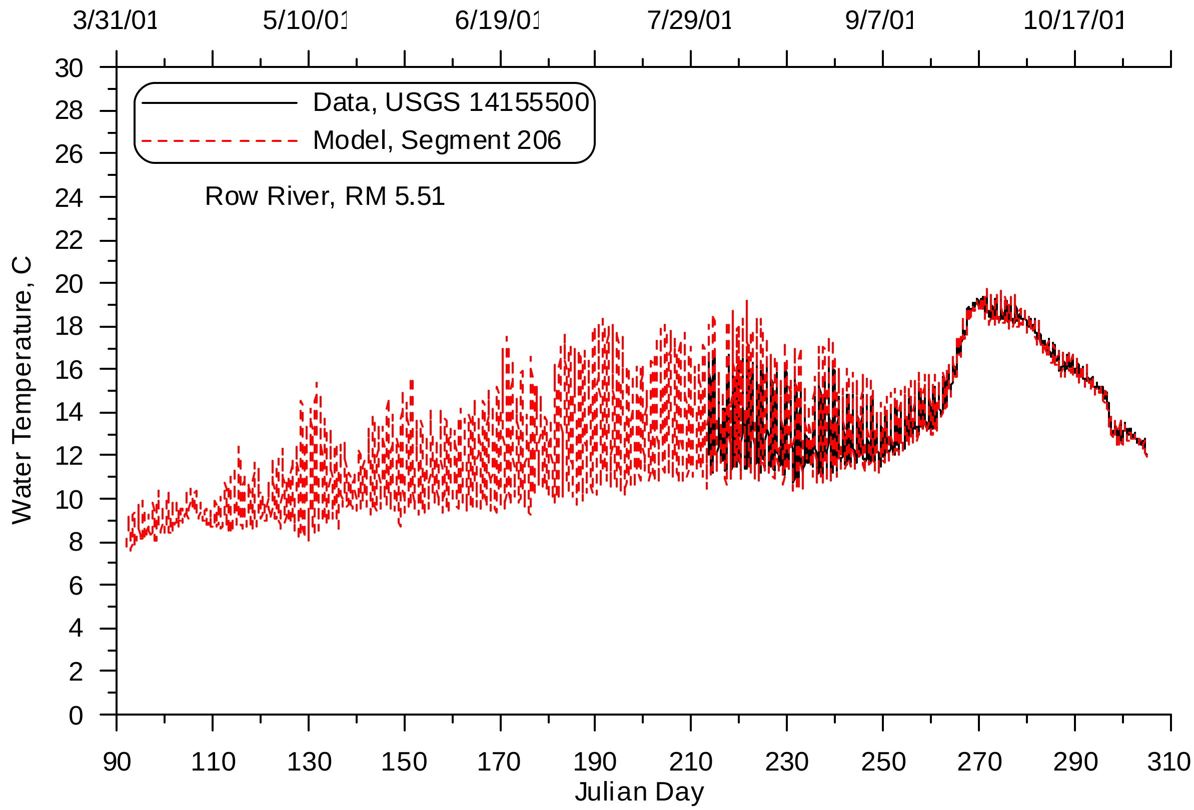

Figure 468: Row River near Cottage Grove model-data continuous temperature comparison, 2001

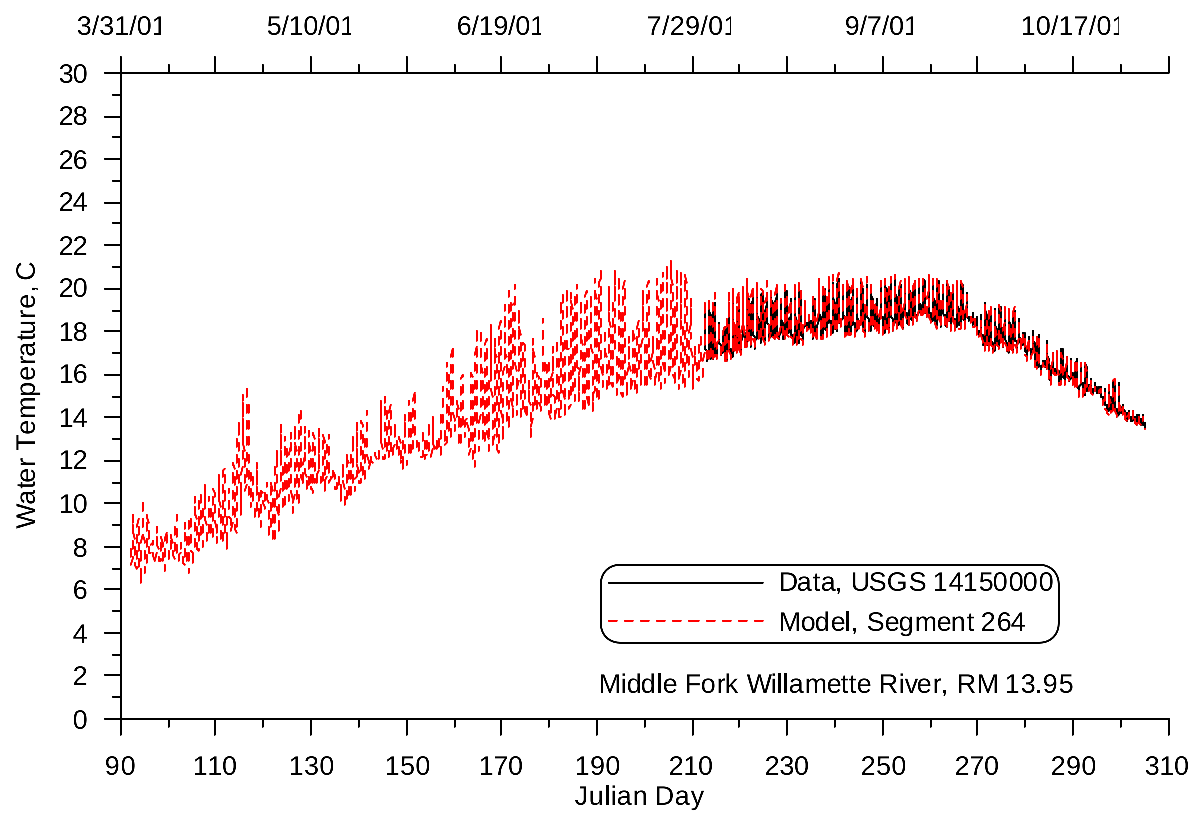

Figure 469: Middle Fork Willamette River near Dexter model-data continuous temperature comparison, 2001

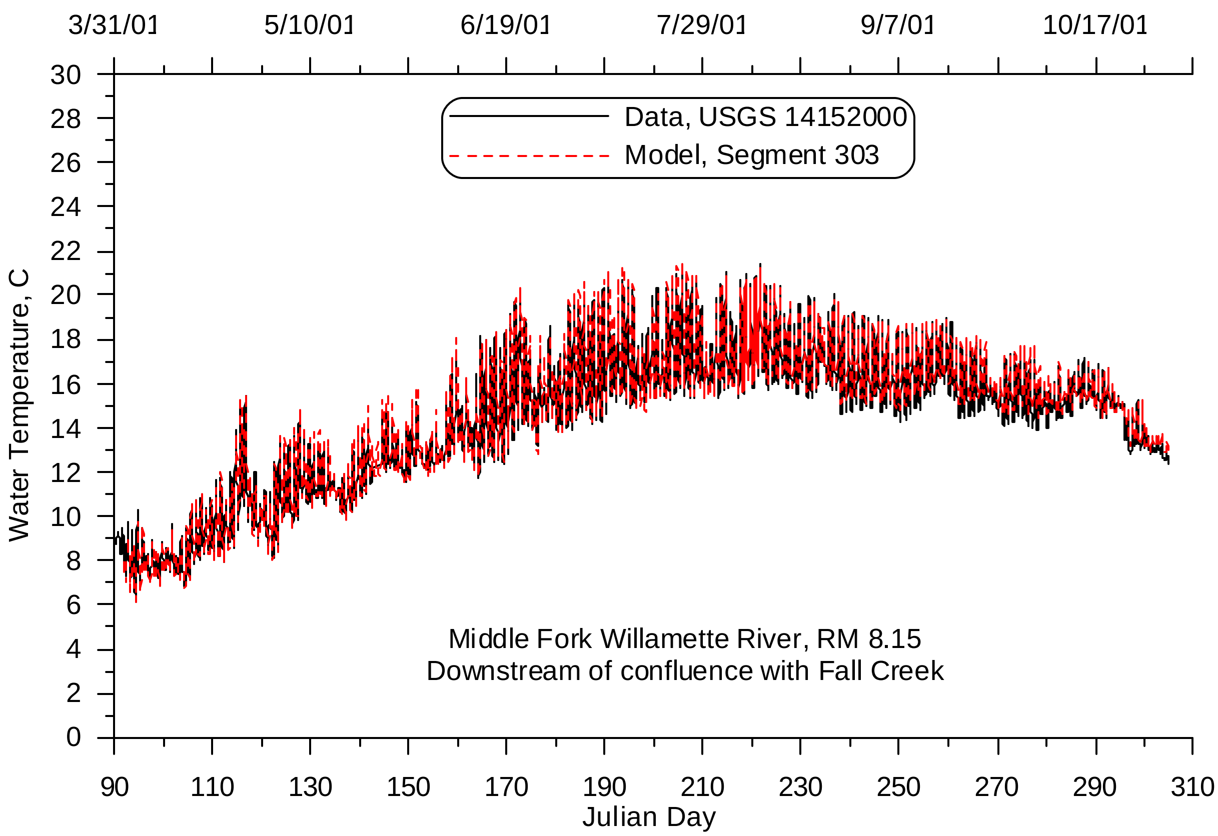

Figure 470: Middle Fork Willamette River at Jasper model-data continuous temperature comparison, 2001

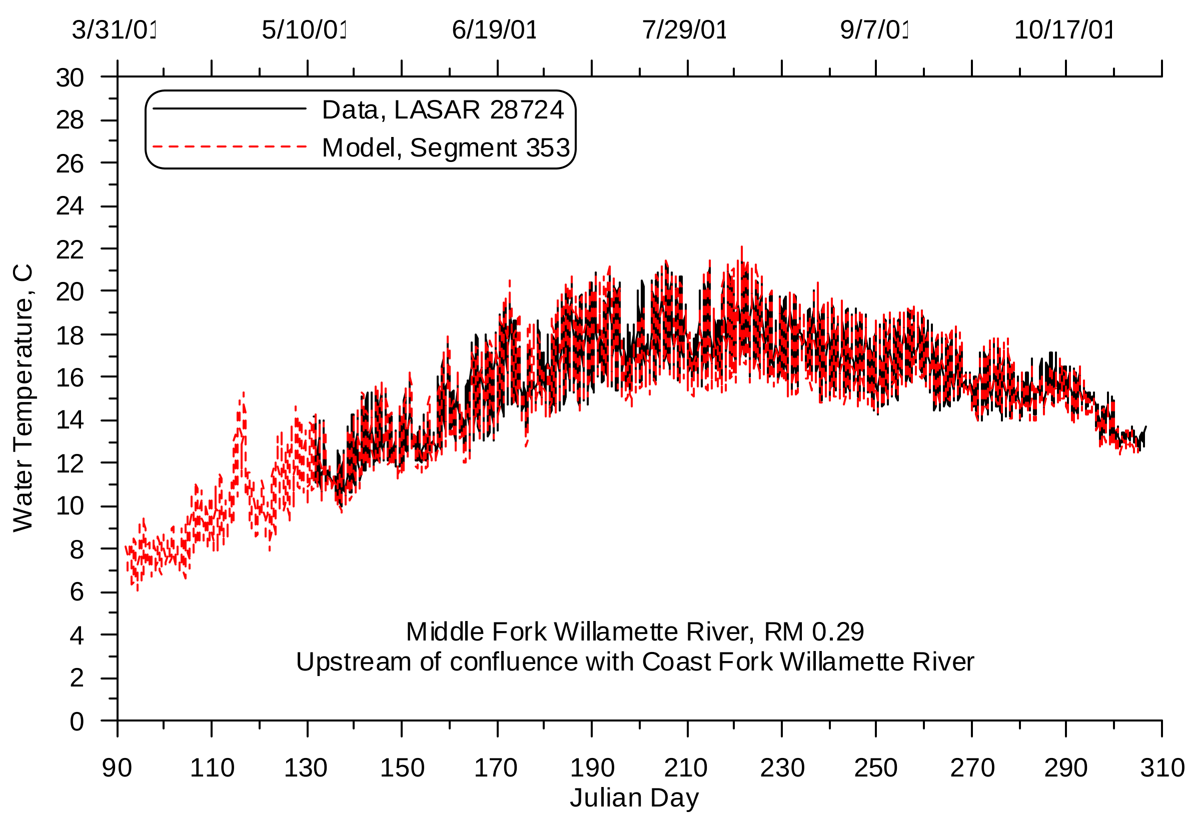

Figure 471: Middle Fork Willamette River near mouth model-data continuous temperature comparison, 2001

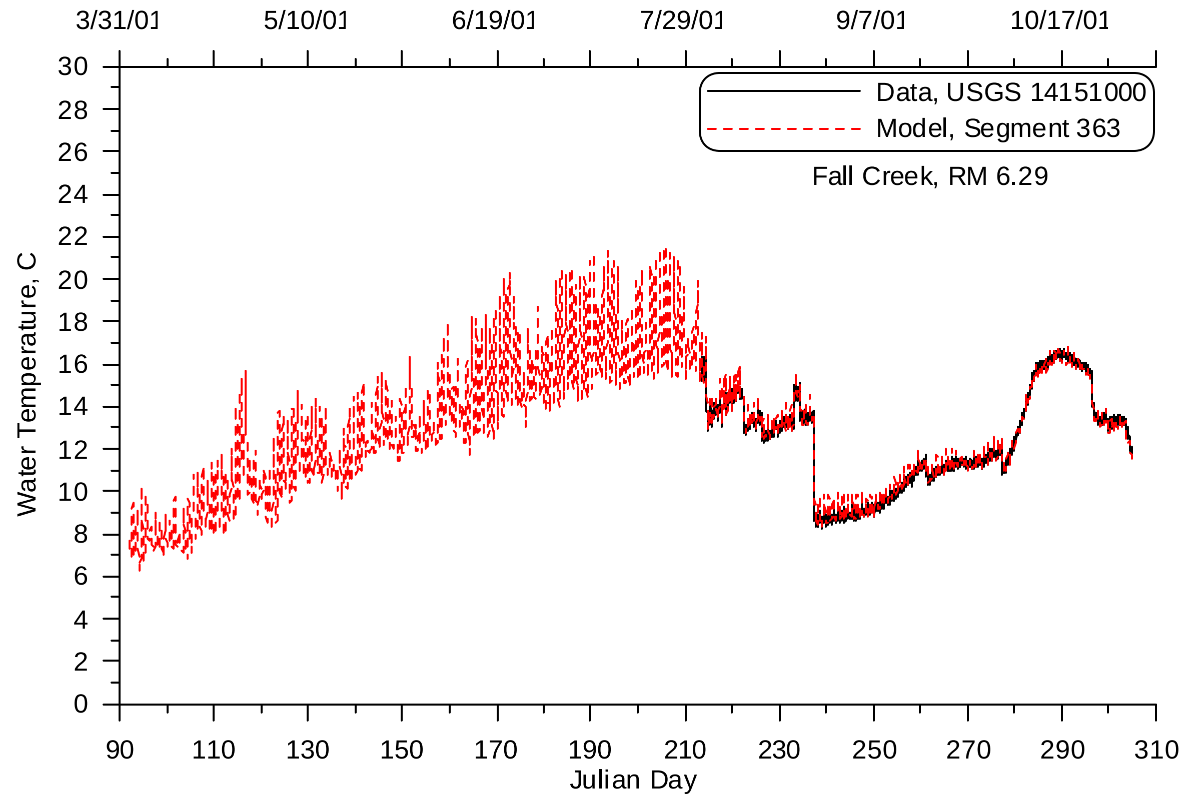

Figure 472: Fall Creek below Winberry Creek model-data continuous temperature comparison, 2001

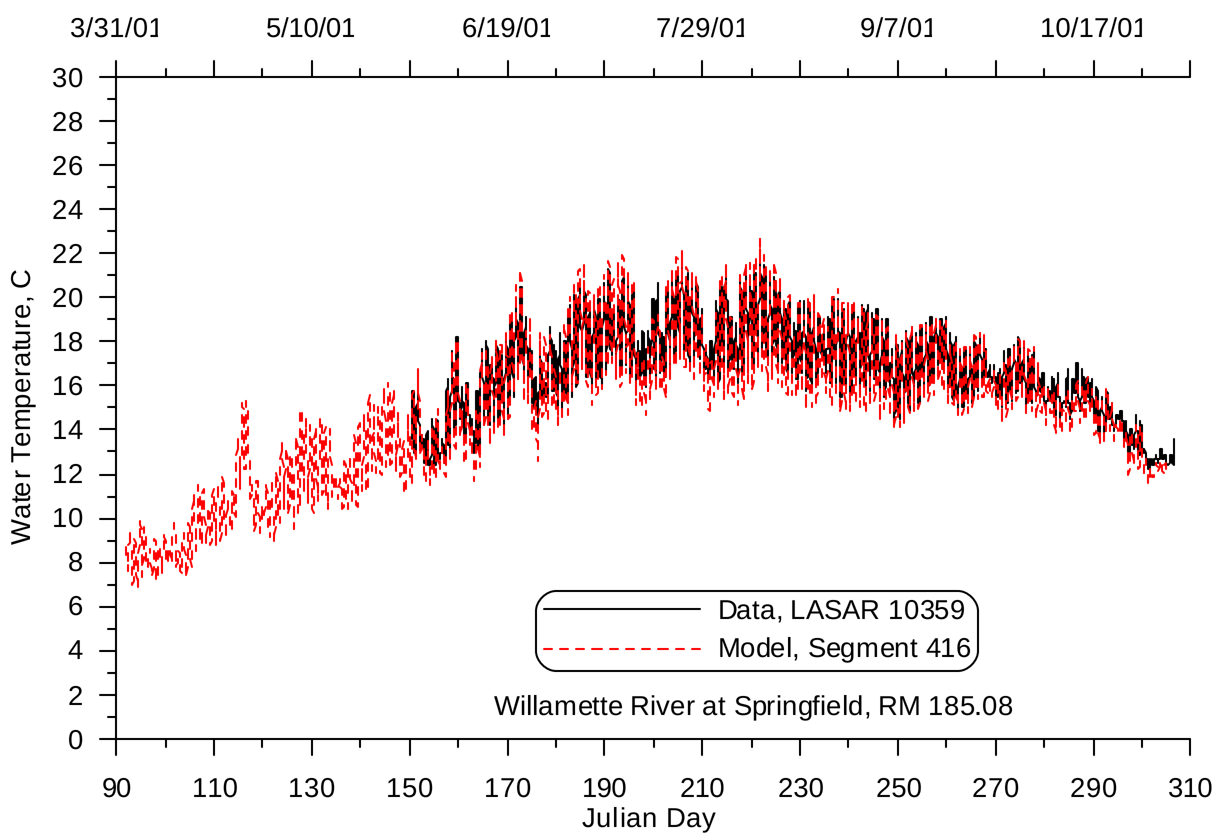

Figure 473: Willamette River at Highway 126 model-data continuous temperature comparison, 2001

Year 2002

Temperatures on the Coast Fork and Middle Fork Willamette River were calibrated from April to October 2002. Table 71 lists the model-data error statistics for continuous temperature model results and data. The table shows absolute mean errors (AME) of less than 0.6 ^{o}C and root mean square error (RMS) of less than 0.9 ^{o}C for sites on the Middle Fork Willamette River, Fall Creek, and the Willamette River main stem. Model-data error statistics were larger for the Coast Fork Willamette River and Row River with AME values less than 1.9 ^{o}C and RMS values less than 2.3 ^{o}C. Overall the mean error shows there is slight bias on the cooler side of about 0.2 ^{o}C. The 2002 model-data error statistics are similar to the 2001 results and indicate there is room for improvement with the Coast Fork Willamette River. Improvements may be obtained by better characterizing the boundary conditions and the river channel bathymetry.

Figure 474 shows a model-data temperature comparison on the Coast Fork Willamette River below the model upstream boundary condition. This site is close to the model upstream boundary condition so model-data comparison is expected to be close as demonstrated by the error statistics of 0.20 ^{o}C. The next downstream site at RM 21.6, above the City of Cottage Grove WWTP effluent discharge, as shown in Figure 475, indicates there is some model-data agreement but the model results show diurnal temperature swings which are too large, which is reflected in the error statistics.

Figure 476 shows a model-data temperature comparison on the Coast Fork Willamette River at Saginaw Bridge (RM 19.3). The model-data temperature comparison shows improved model results compared to the site upstream but the diurnal temperature swings from the model are still large compared with data. The site downstream for comparing model result with data is at Creswell, OR on the Coast Fork Willamette River at RM 12.3. Figure 477 shows a plot comparing the continuous temperatures from the model and data and indicates there is some model-data agreement but similar to sit immediately upstream the model is showing too large of diurnal temperature swings.

Figure 478 shows a model-data continuous temperature comparison on the Coast Fork Willamette River at RM 5.7, near Goshen, OR. This figure shows there is some model-data agreement but the model is predicting too large of temperature swings compared to the data.

In 2002 there was an additional monitoring site on Row River at RM 6.7. Figure 479 compares the half-hourly temperature data collected at this site with the model. The figure indicates there is good model data agreement but the model's daily peak temperatures are higher at times than the data.

Figure 480 shows a plot of a model-data continuous temperature comparison on Row River at RM 5.5. The figure indicates there is good agreement between the model and data with model showing slightly larger diurnal temperature swings than the data.

Figure 481 shows a plot of model-data temperature time series comparison on the Middle Fork Willamette River at RM 14. This site is 2.5 miles downstream from the upstream boundary condition on the river so the model is expected to be close to the data. The figure indicates there is good agreement between the model and data with an RMS of 0.2 ^{o}C.

Downstream of the confluence with Fall Creek at RM 8.2 continuous temperature measurements were recorded on the Middle Fork Willamette River and compared with model results in Figure 482. The figure indicates there is good agreement between the model and data with the model matching the diurnal temperature cycles in the data.

Figure 483 shows a plot comparing the continuous temperature model results with data on the Middle Fork Willamette River just upstream of the confluence with the Coast Fork Willamette River. The figure shows there is good model-data agreement with the model showing time periods when the diurnal temperature cycles were slightly larger than the data.

As in 2001 there was only one continuous temperature monitoring site on Fall Creek (RM 6.3) in 2002. The site is 0.8 miles downstream from the upstream boundary condition so the model results are expected to be close to the data. Figure 484 shows there is good model-data agreement with the model showing higher daily peak temperature than the data.

The furthest downstream location in the model corresponds to the RM 185.1 on the main stem of the Willamette River where highway 126 crosses the river. Figure 485 shows a plot of a model-data temperature comparison and indicates there is good model-data agreement with the model having slightly larger diurnal temperature swings in the early summer.

Table 71: Coast and Middle Fork Willamette River continuous water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Continuous Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
USGS 14153500	28.69	4	10105	0.04	0.11	0.17
LASAR 29643	21.60	49	5955	-1.24	1.81	2.23
LASAR 10381	19.34	63	5954	-0.38	0.94	1.16
LASAR 10380	12.27	109	6081	0.47	0.61	1.01
USGS 14157500	5.72	153	10174	-0.95	1.29	1.62
LASAR 10991	6.74	199	6082	0.95	1.22	1.74
USGS 14155500	5.51	206	10174	0.39	0.58	0.86
USGS 14150000	13.95	264	10173	0.02	0.16	0.21
USGS 14152000	8.15	303	10173	-0.08	0.28	0.36
LASAR 28724	0.29	353	4256	-0.30	0.40	0.51
USGS 14151000	6.29	363	10173	0.11	0.41	0.58
LASAR 10359	185.08	416	5761	-0.39	0.50	0.69

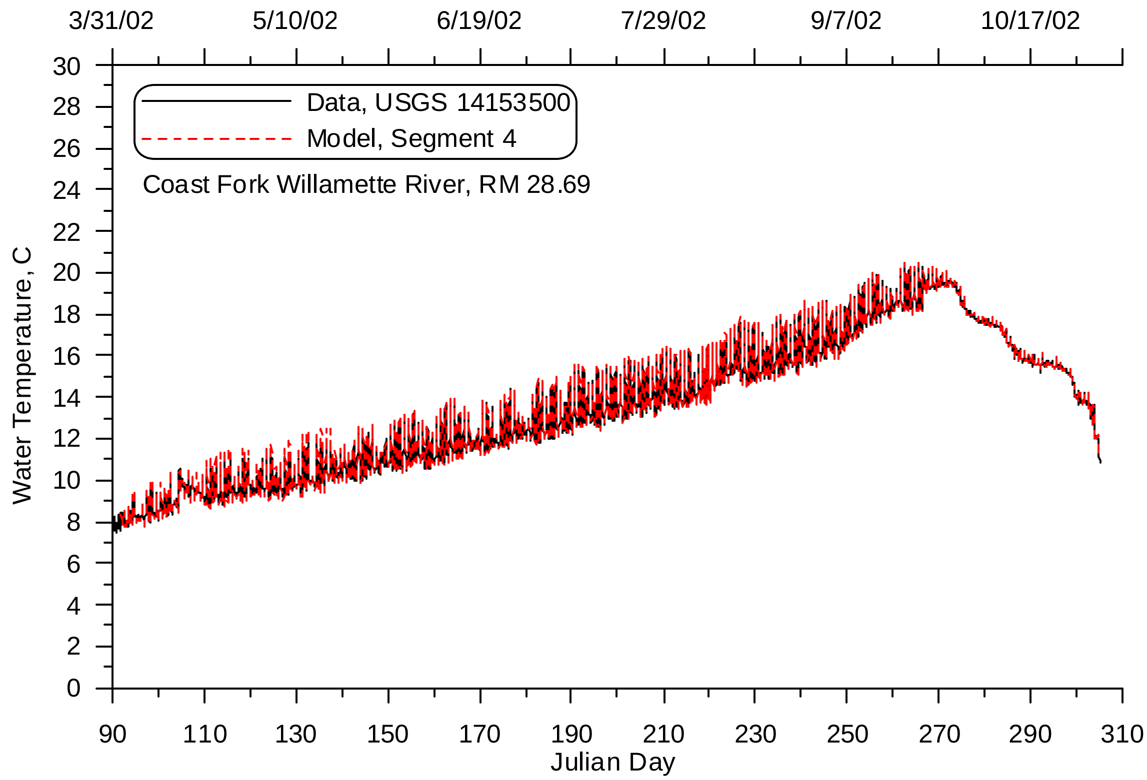

Figure 474: Coast Fork Willamette River below Cottage Grove Dam model-data continuous temperature comparison, 2002

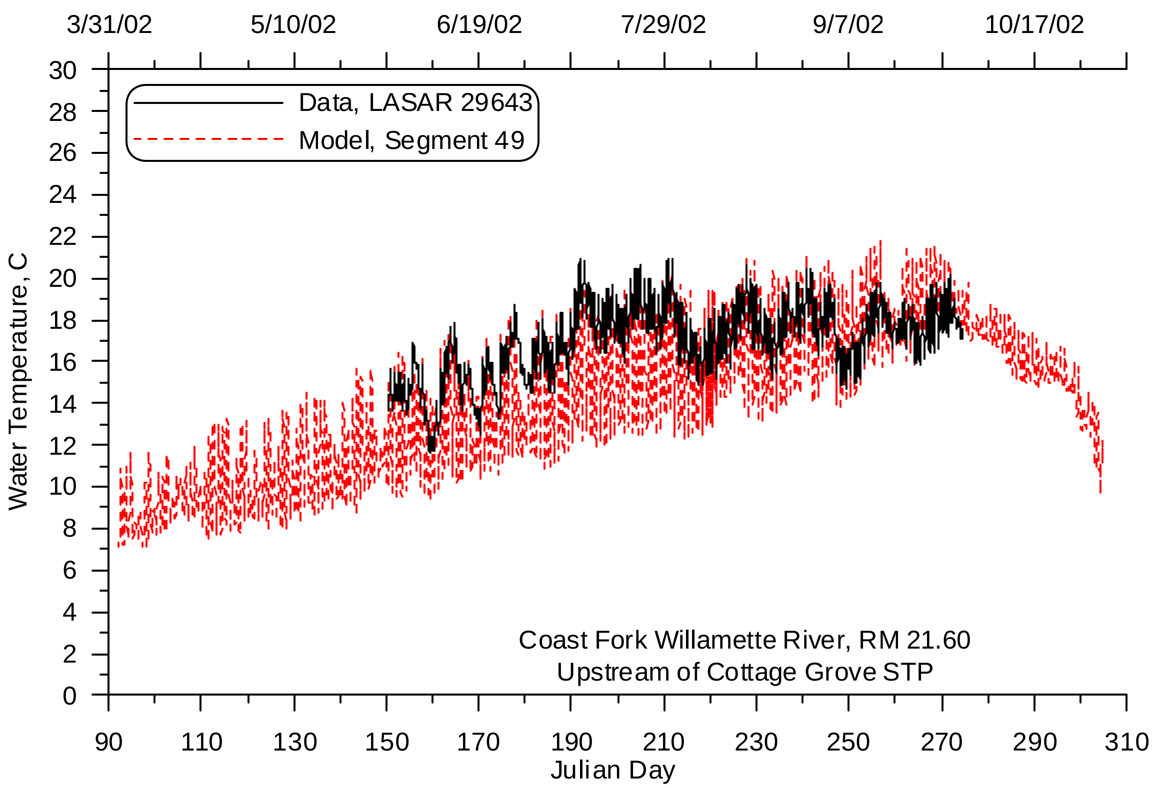

Figure 475: Coast Fork Willamette River above Cottage Grove WWTP model-data continuous temperature comparison, 2002

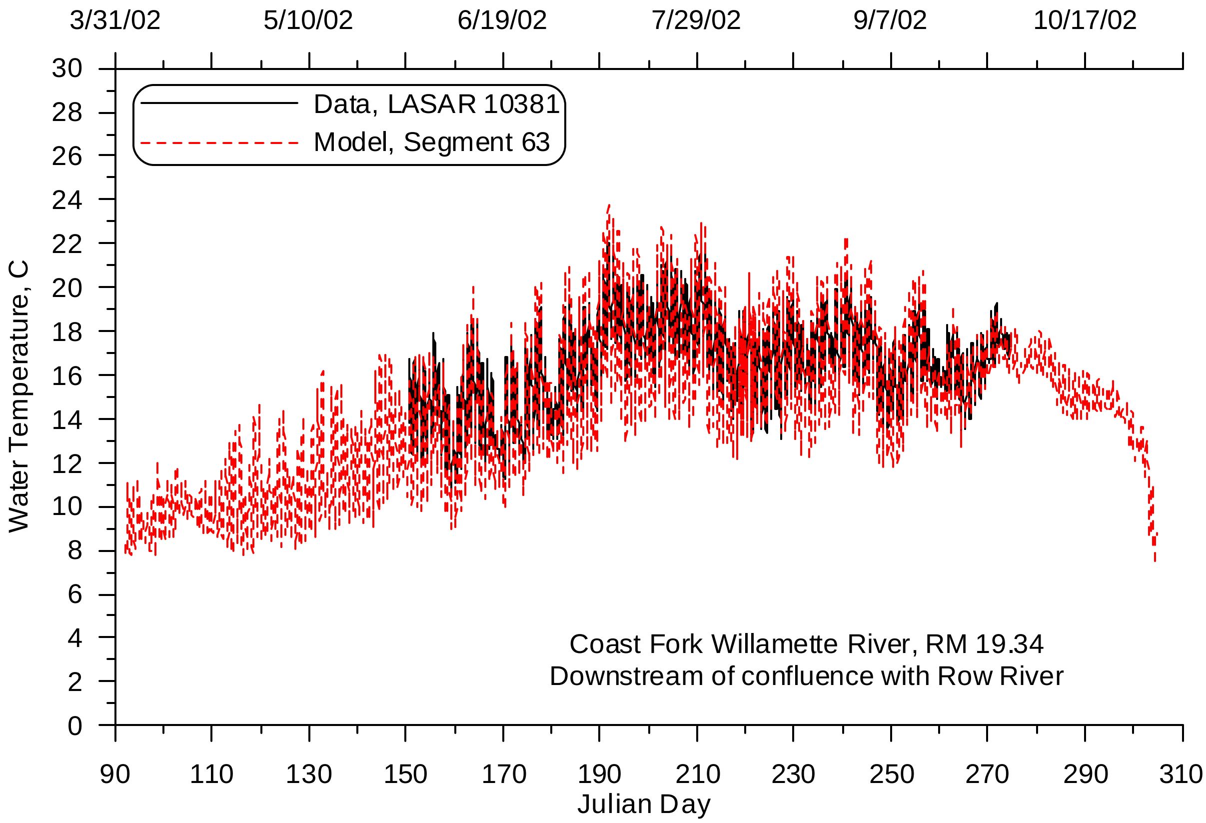

Figure 476: Coast Fork Willamette River at Saginaw Bridge model-data continuous temperature comparison, 2002

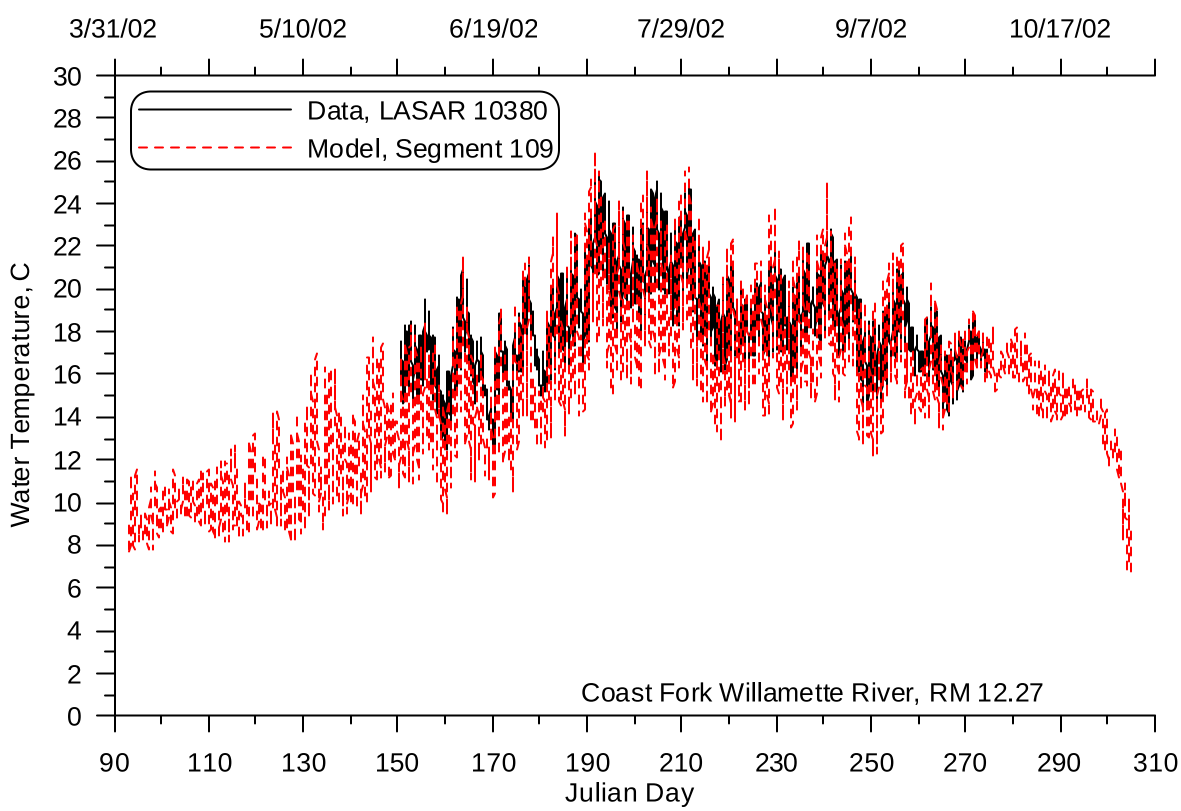

Figure 477: Coast Fork Willamette River at Creswell model-data continuous temperature comparison, 2002

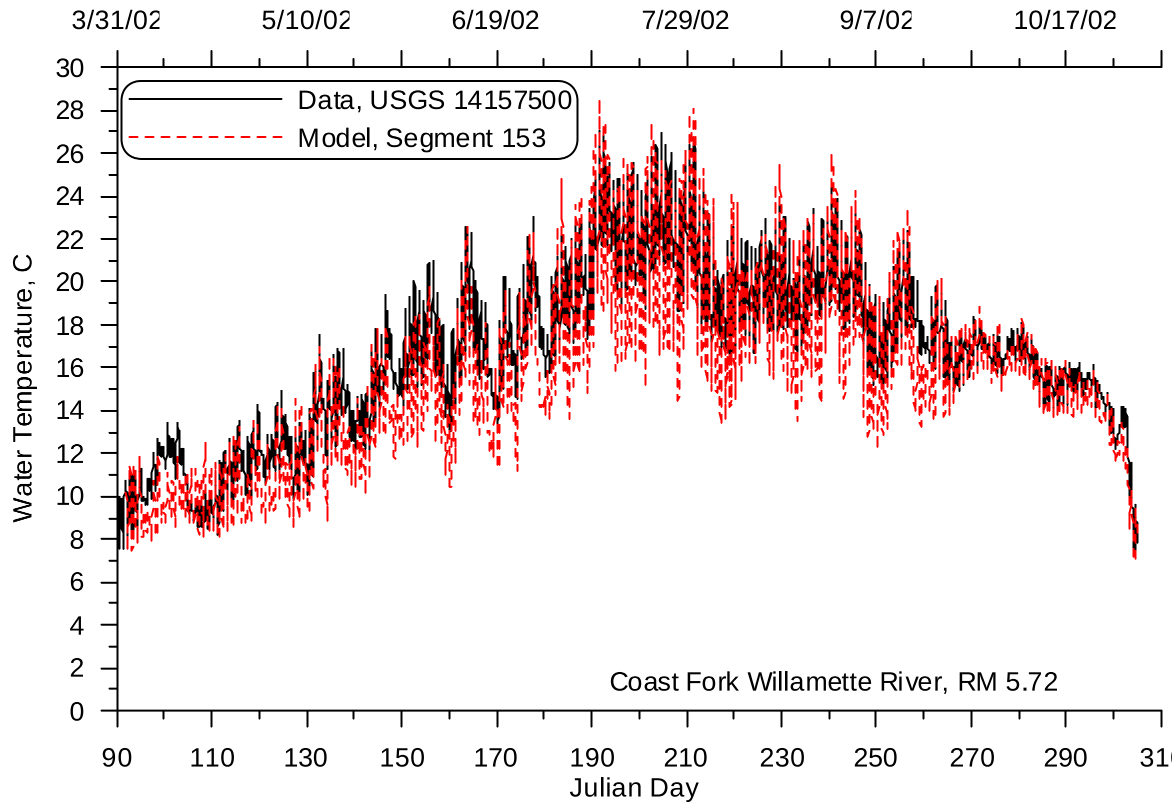

Figure 478: Coast Fork Willamette River near Goshen model-data continuous temperature comparison, 2002

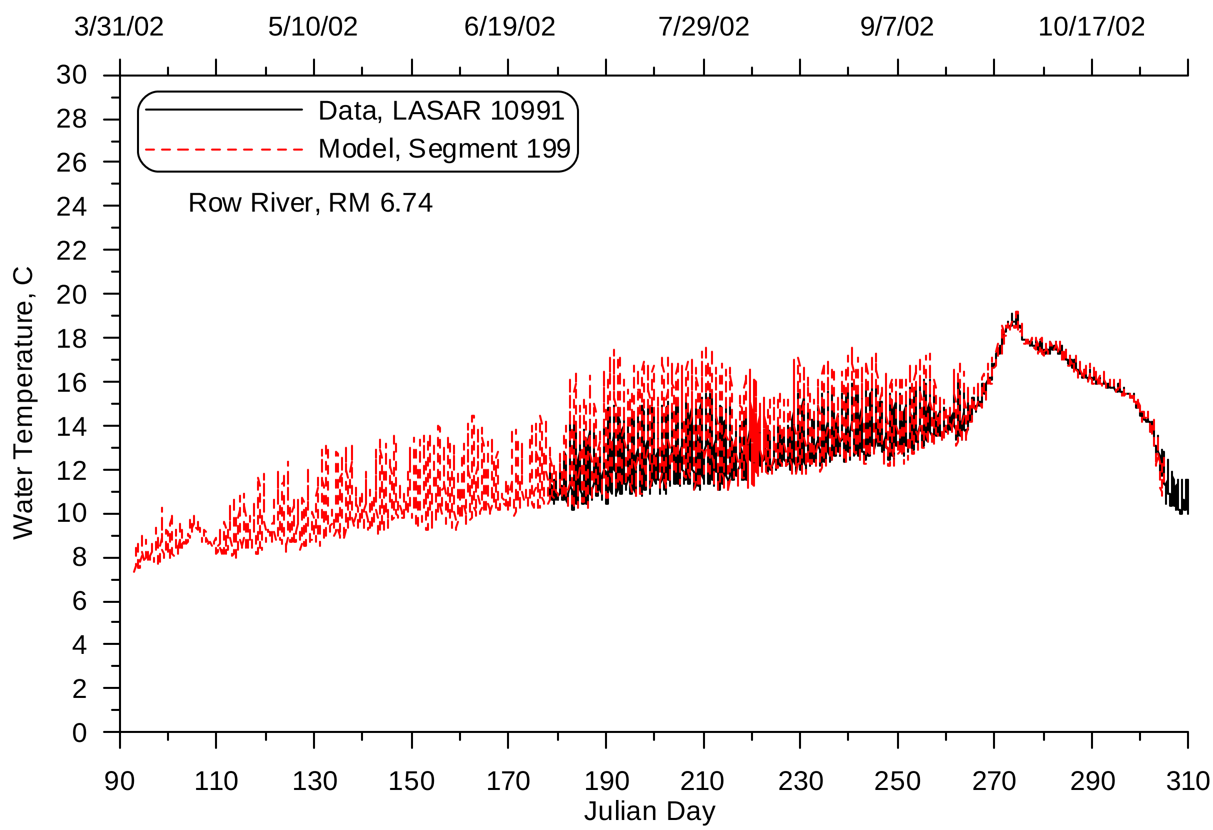

Figure 479: Row River below Dorena Reservoir model-data continuous temperature comparison, 2002

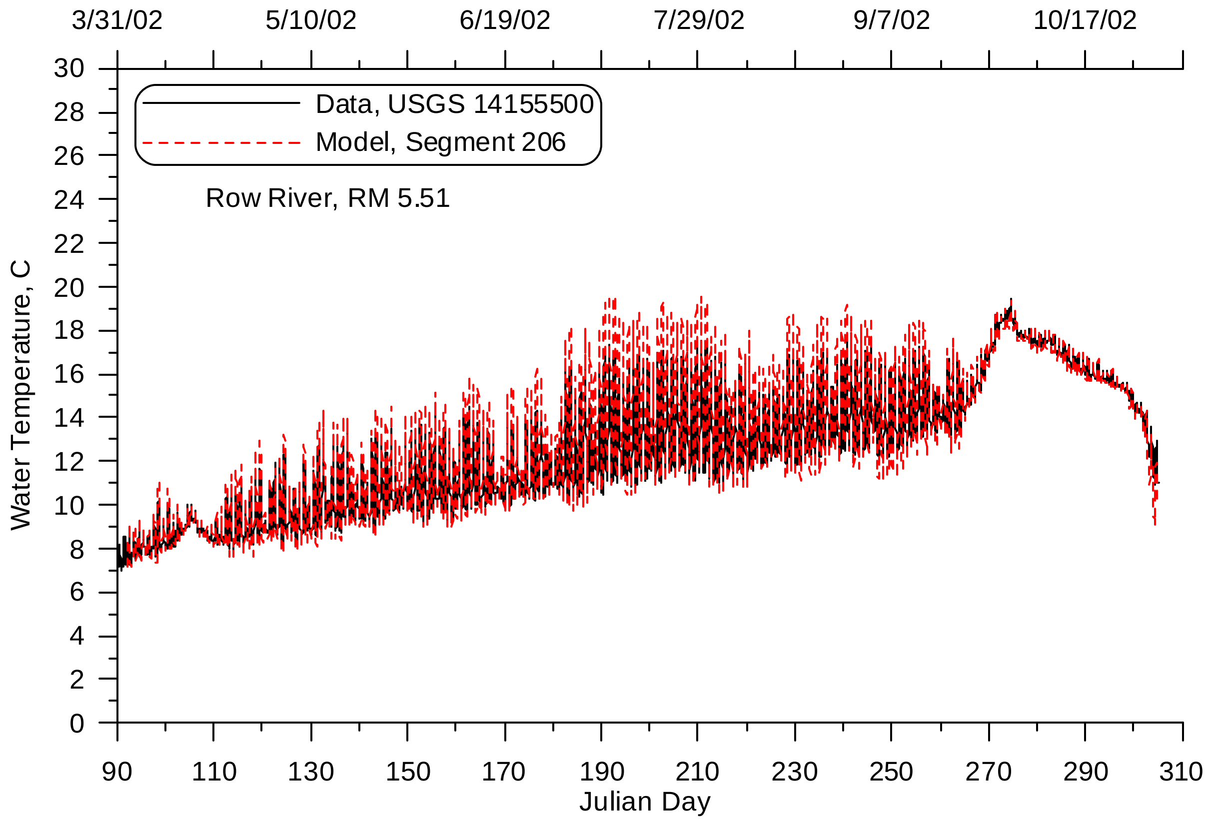

Figure 480: Row River near Cottage Grove model-data continuous temperature comparison, 2002

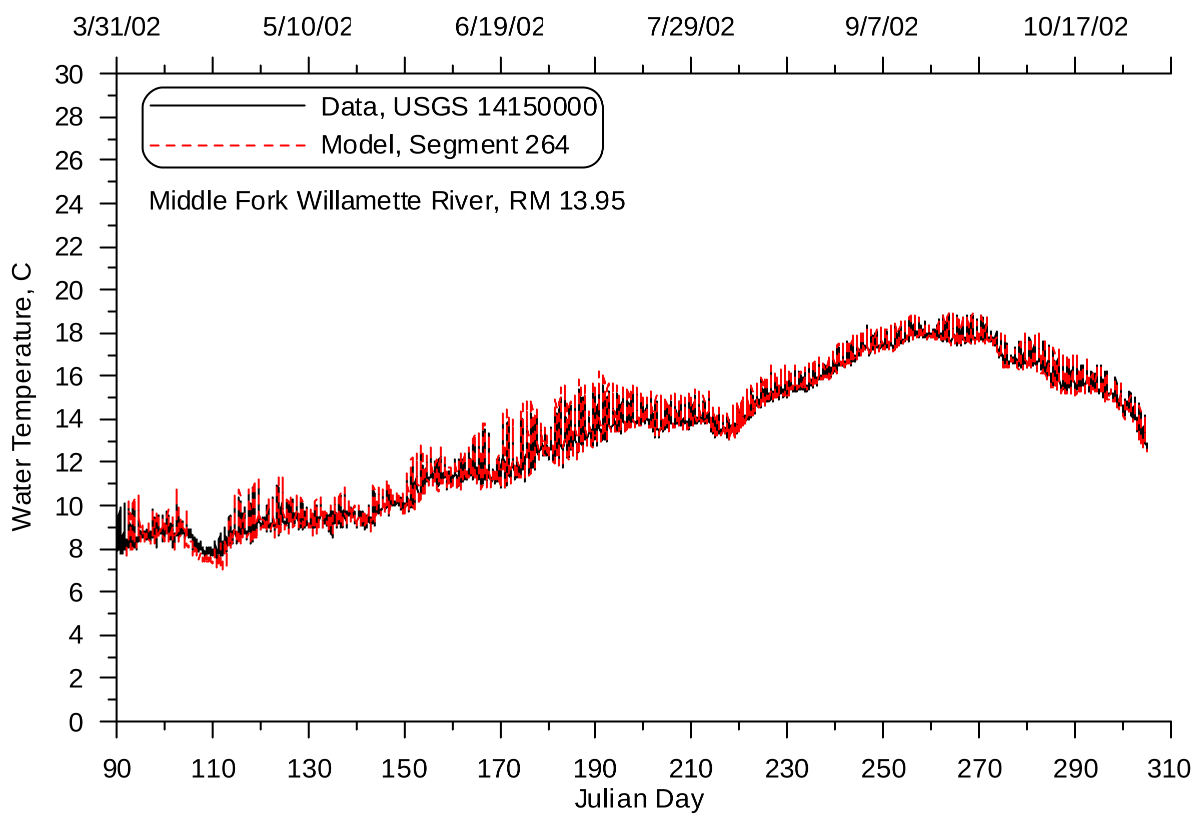

Figure 481: Middle Fork Willamette River near Dexter model-data continuous temperature comparison, 2002

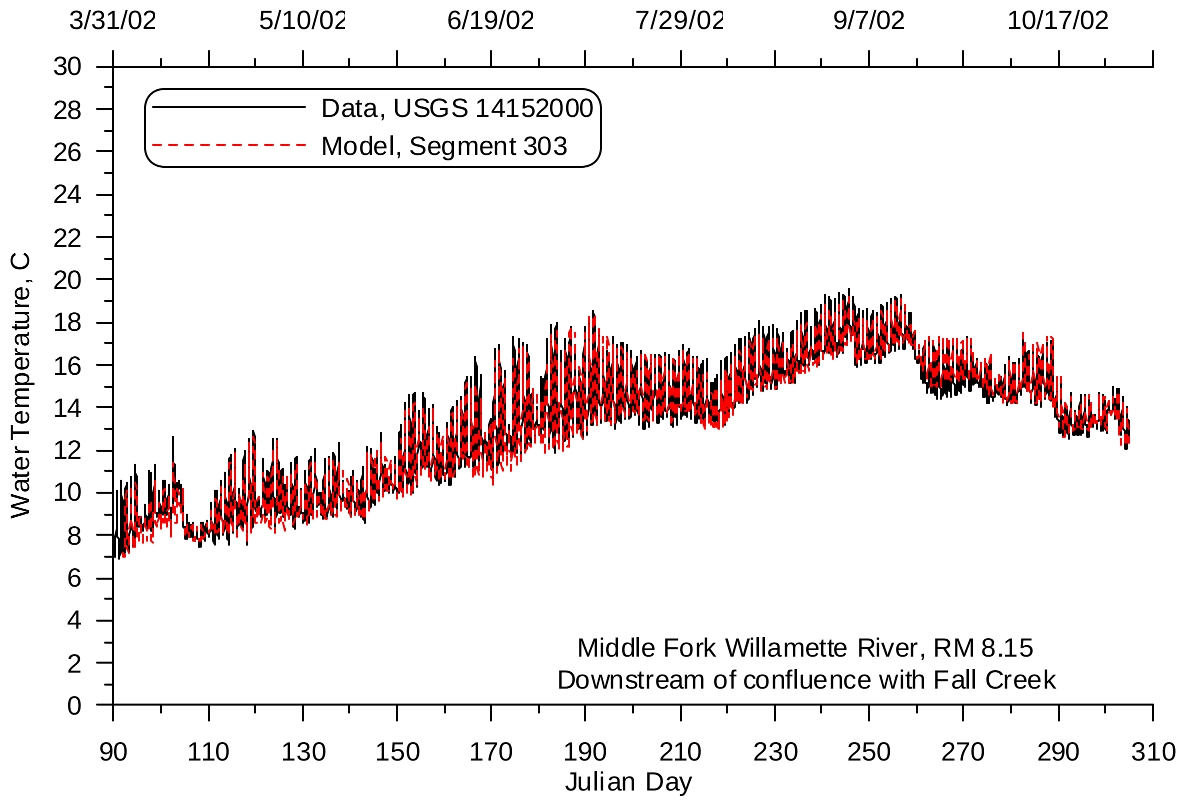

Figure 482: Middle Fork Willamette River at Jasper model-data continuous temperature comparison, 2002

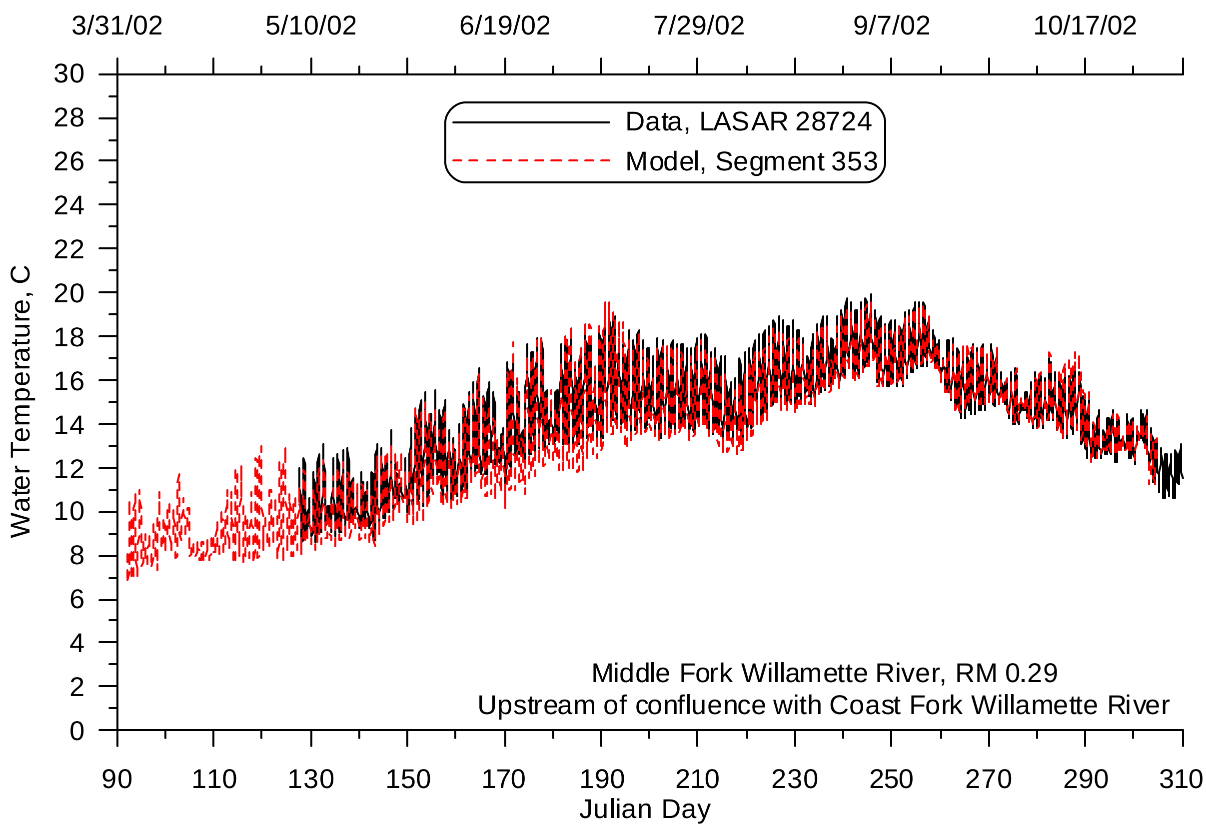

Figure 483: Middle Fork Willamette River near mouth model-data continuous temperature comparison, 2002

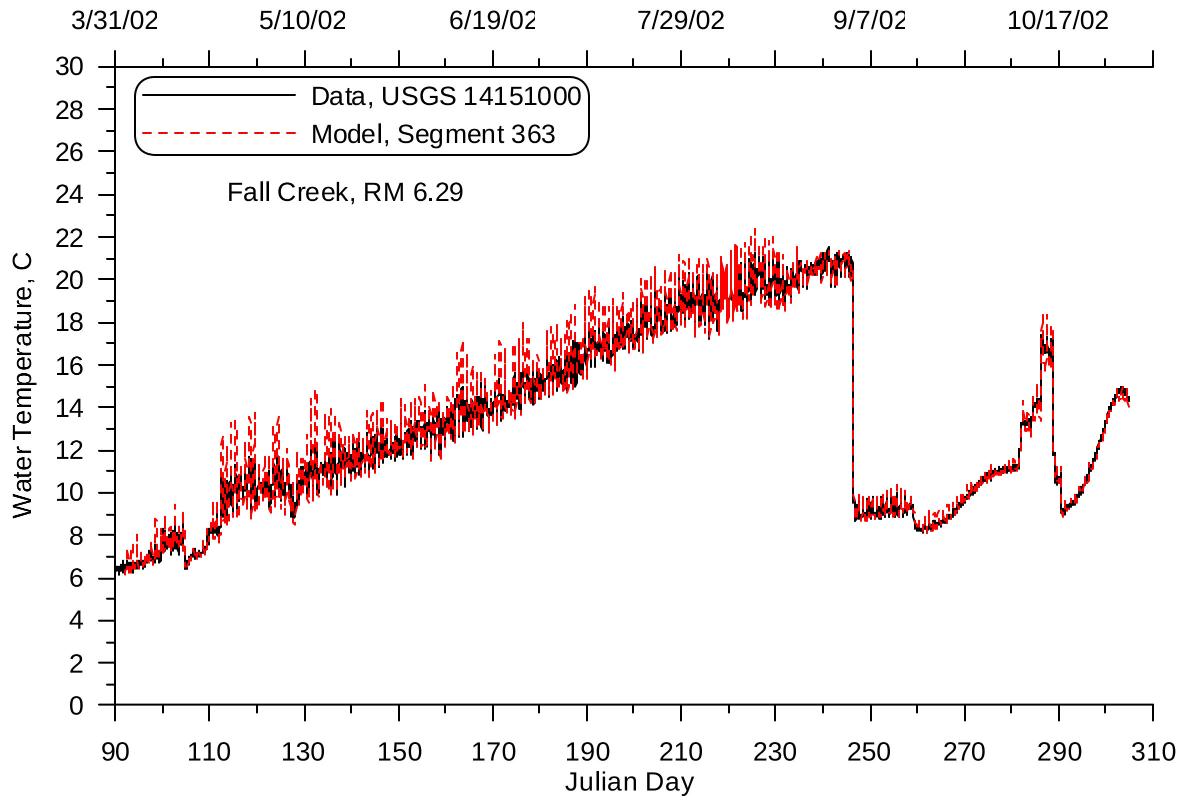

Figure 484: Fall Creek below Winberry Creek model-data continuous temperature comparison, 2002

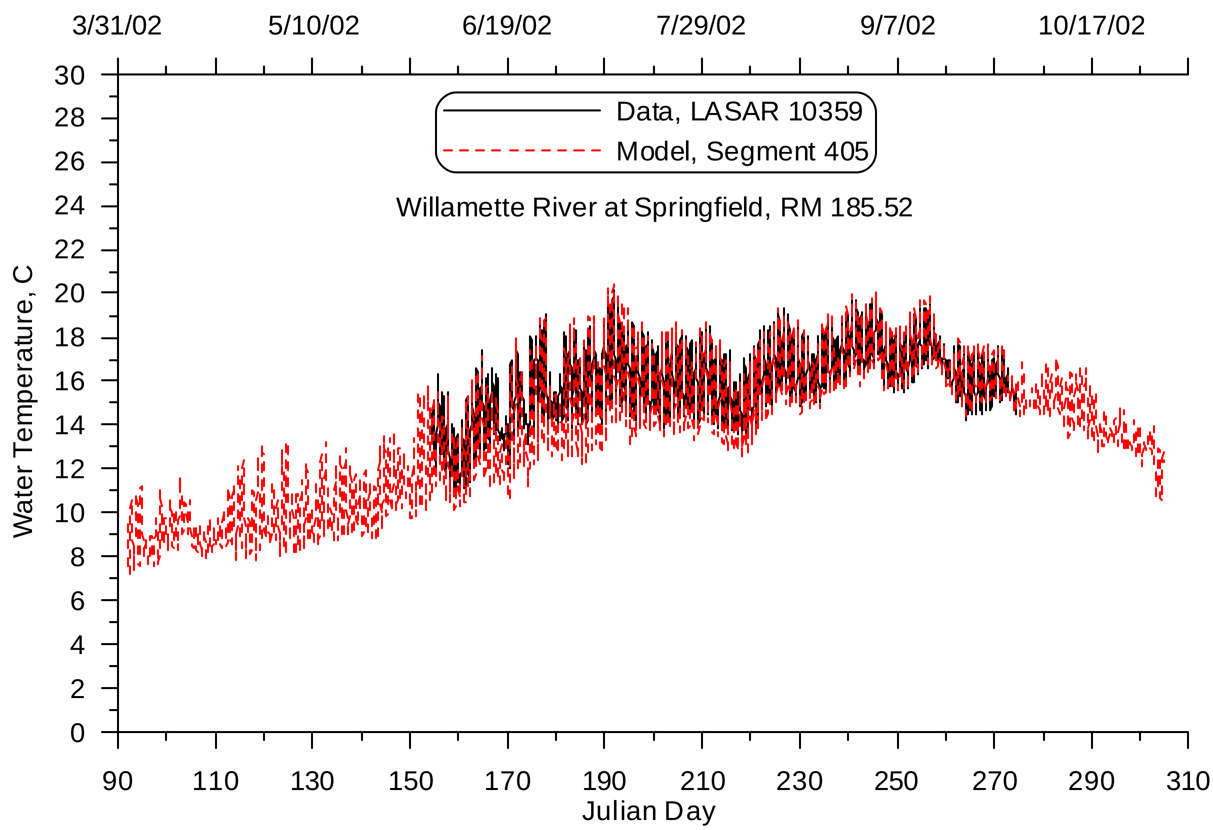

Figure 485: Willamette River at Highway 126 model-data continuous temperature comparison, 2002

Daily Maximum Temperatures

Year 2001

Temperatures on the Coast Fork and Middle Willamette River model were calibrated from April through the end of October 2001. Table 59 lists the model-data error statistics for the daily maximum temperature. The table shows absolute mean errors (AME) of less than 1.3 ^{o}C and root mean square error (RMS) of less than 1.6 ^{o}C. Overall the mean error shows there is slight bias warmer of about 0.01 ^{o}C.

Figure 486 to Figure 490 show model-data daily maximum temperature comparisons on the Coast Fork Willamette River and Row River. These figures show the model is in relative agreement with the data but as shown in the continuous temperature result there are periods when the model is under predicting and over predicting daily maximum temperatures when compared with the data.

Figure 491 to Figure 494 show model-data daily maximum temperature comparisons for the Middle Fork Willamette River and Fall Creek. The figures show there is consistently good model-data agreement over the simulation period.

Figure 495 shows a plot of a time series daily maximum temperature comparison between the model and data at RM 185.1 on the main stem of the Willamette River. This figure indicates there is good model-data agreement.

Table 72: Coast and Middle Fork Willamette River daily maximum water temperature calibration model-data error statistics, 2001

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, ^{o}C	AME, ^{o}C	RMS, ^{o}C
USGS 14153500	28.69	4	91	-0.04	0.09	0.11
LASAR 29643	21.60	49	No data			
LASAR 10381	19.34	63	157	0.40	1.05	1.30
LASAR 10380	12.27	109	157	-0.36	0.77	0.98
USGS 14157500	5.72	153	78	-1.16	1.21	1.57
LASAR 10991	6.74	199	No data			
USGS 14155500	5.51	206	92	0.63	0.66	0.90
USGS 14150000	13.95	264	93	0.13	0.18	0.22
USGS 14152000	8.15	303	210	0.14	0.32	0.41
LASAR 28724	0.29	353	175	0.05	0.36	0.51
USGS 14151000	6.29	363	92	0.27	0.35	0.42
LASAR 10359	185.08	416	156	0.01	0.42	0.53

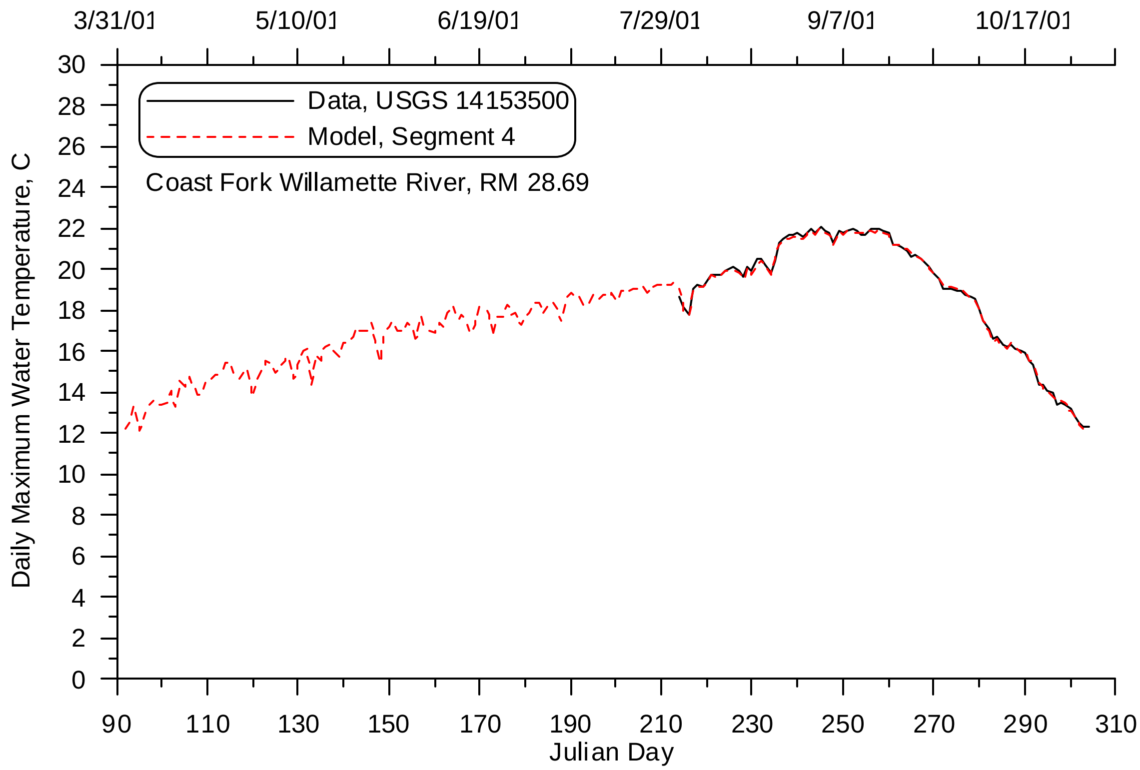

Figure 486: Coast Fork Willamette River below Cottage Grove Dam model-data daily maximum temperature comparison, 2001

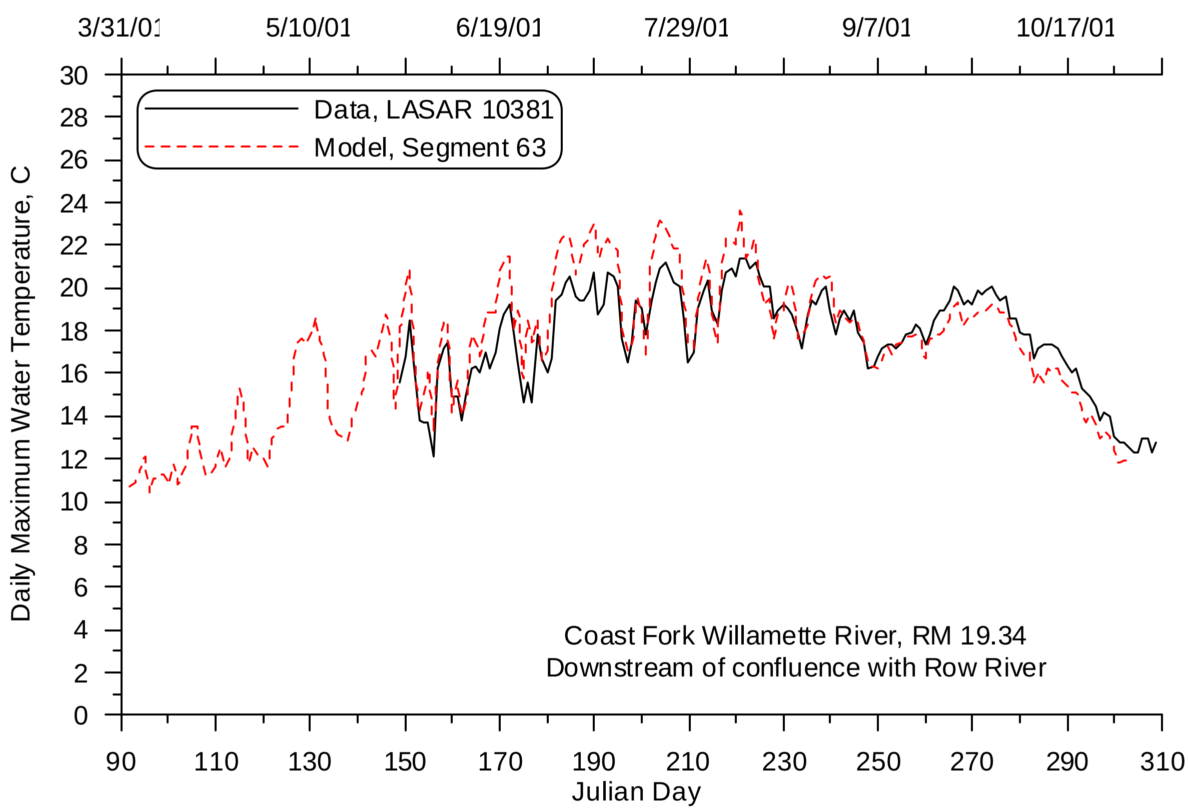

Figure 487: Coast Fork Willamette River at Saginaw Bridge model-data daily maximum temperature comparison, 2001

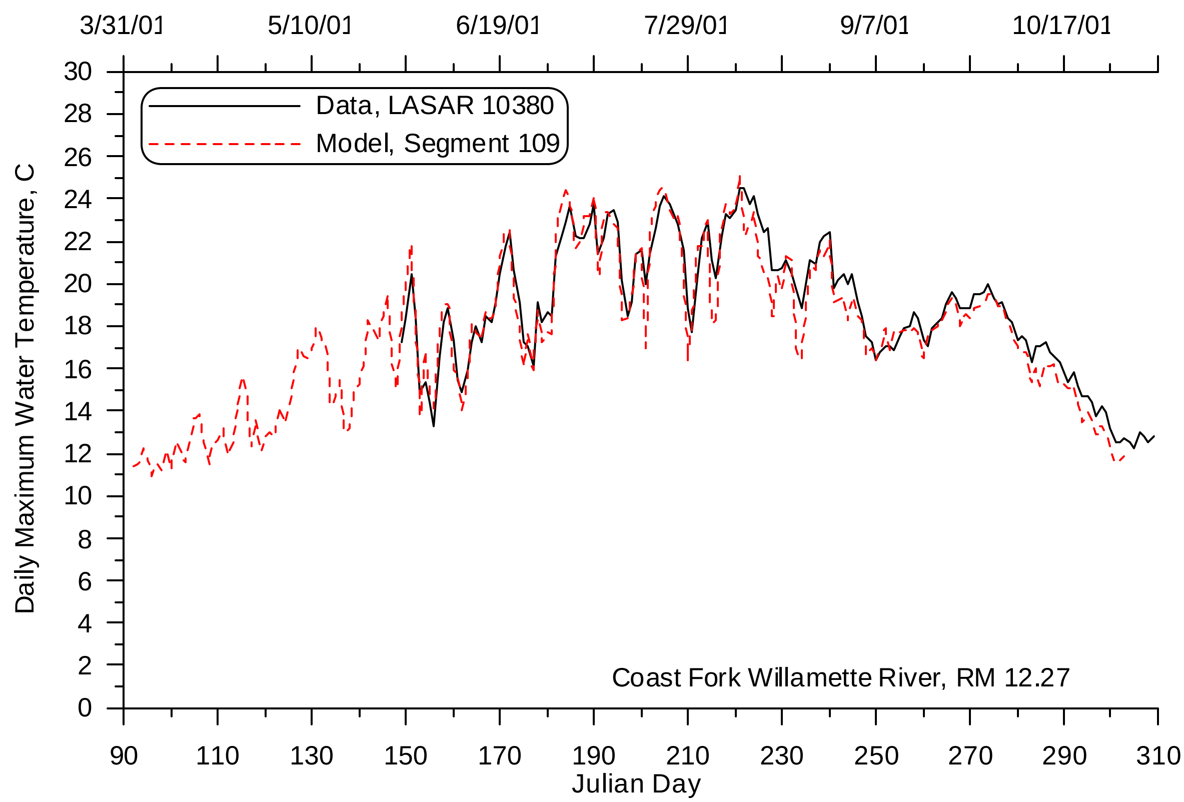

Figure 488: Coast Fork Willamette River at Creswell model-data daily maximum temperature comparison, 2001

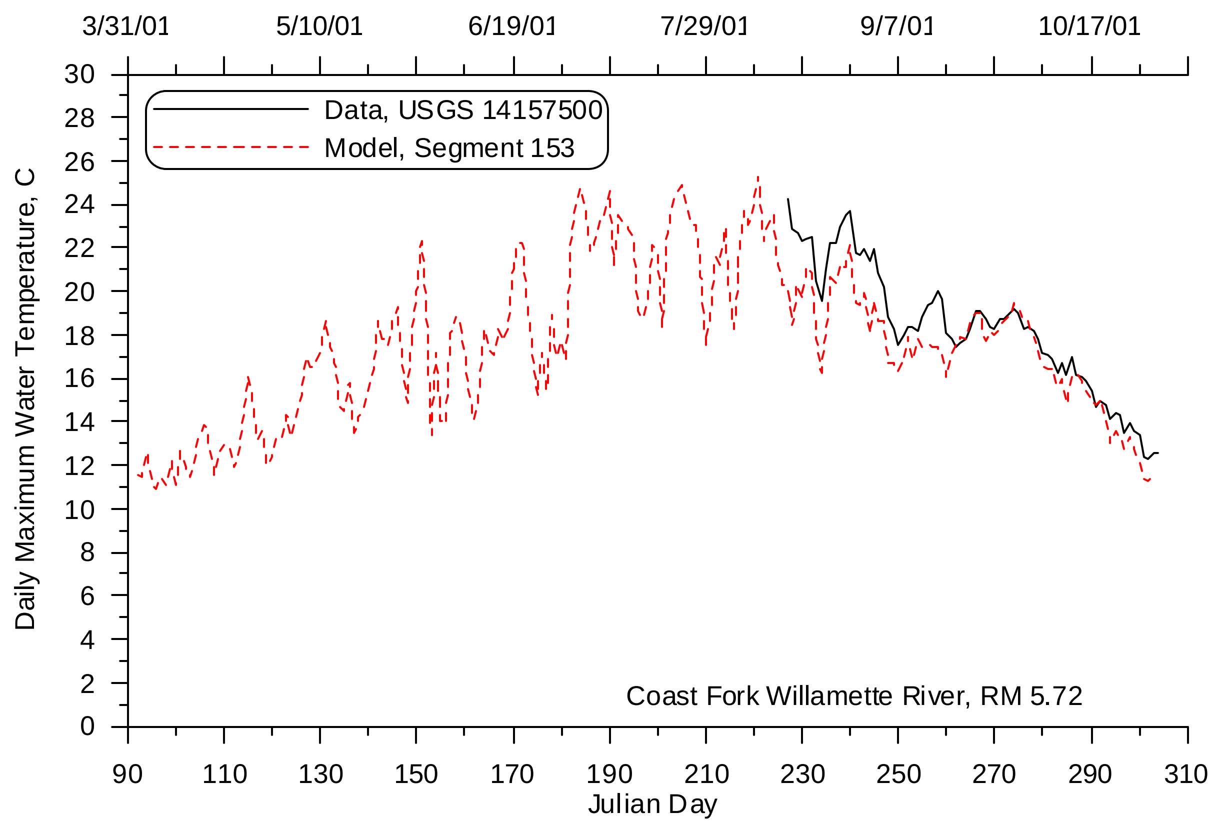

Figure 489: Coast Fork Willamette River near Goshen model-data daily maximum temperature comparison, 2001

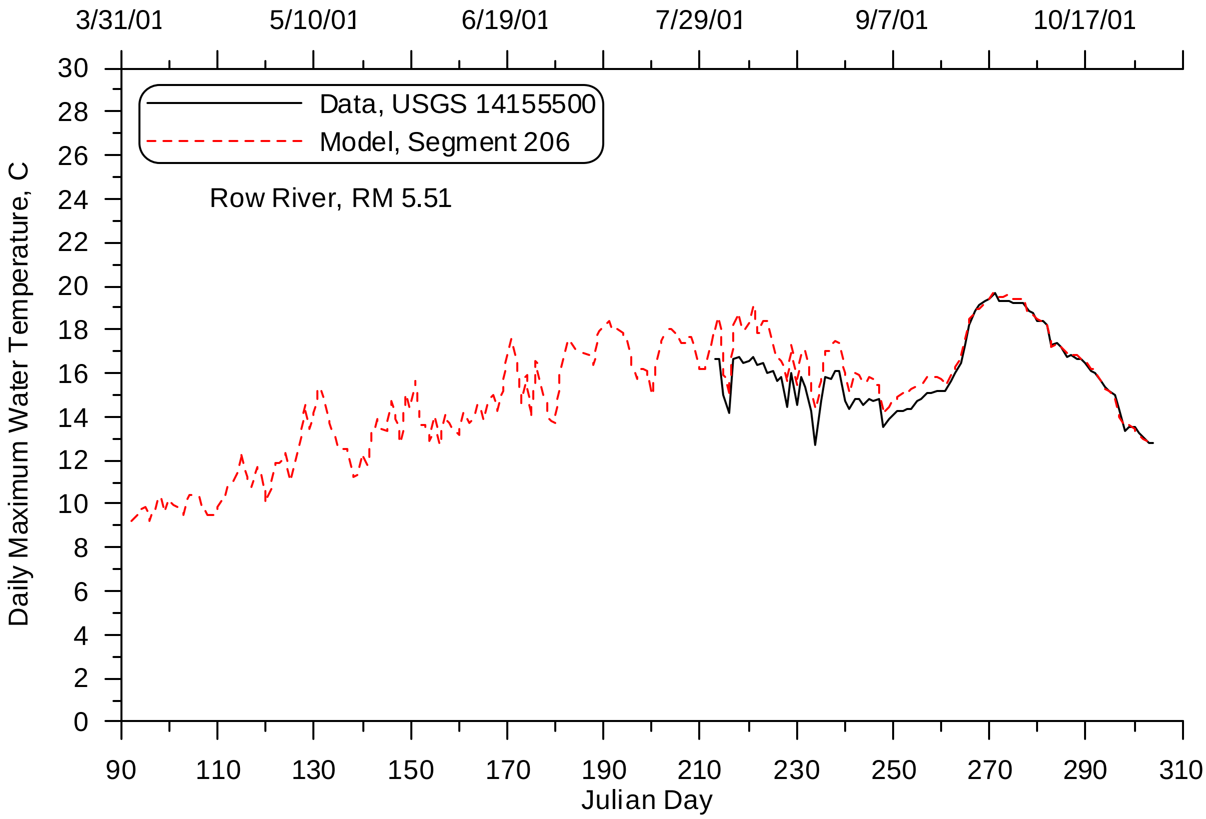

Figure 490: Row River near Cottage Grove model-data continuous temperature comparison, 2001

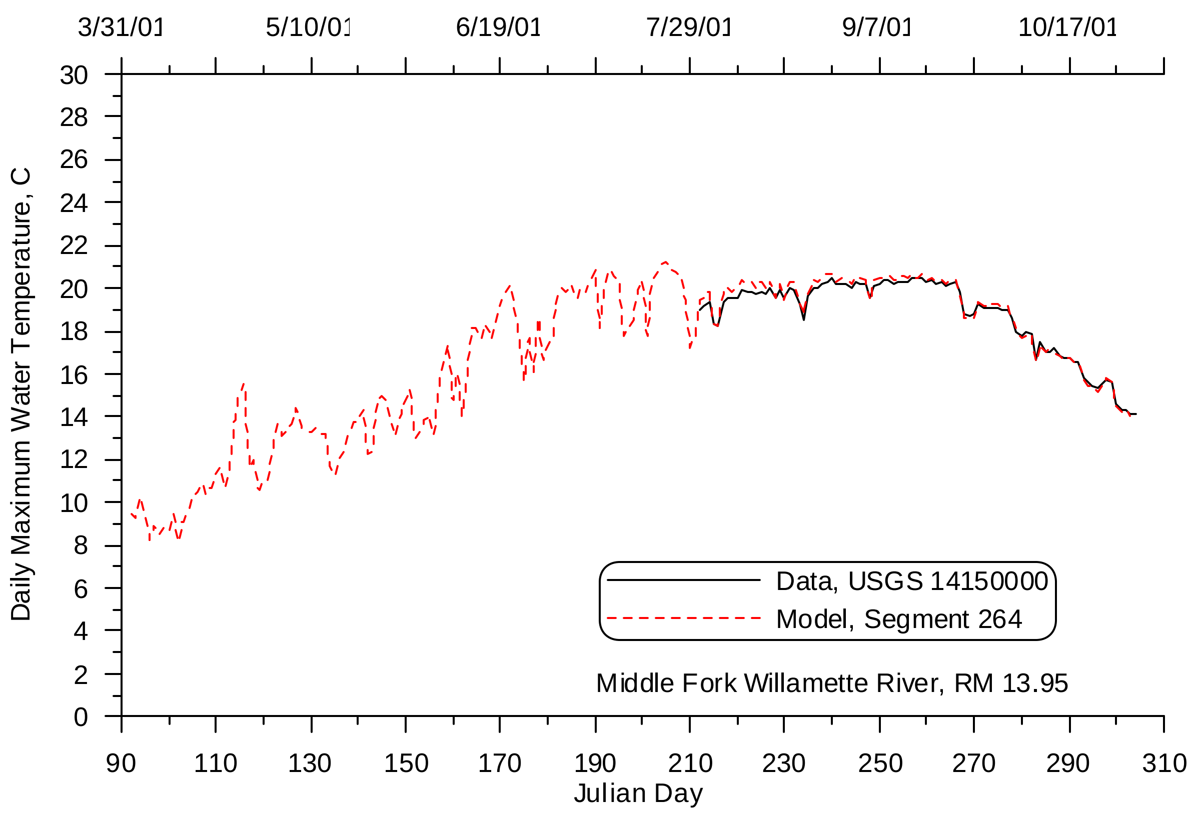

Figure 491: Middle Fork Willamette River near Dexter model-data daily maximum temperature comparison, 2001

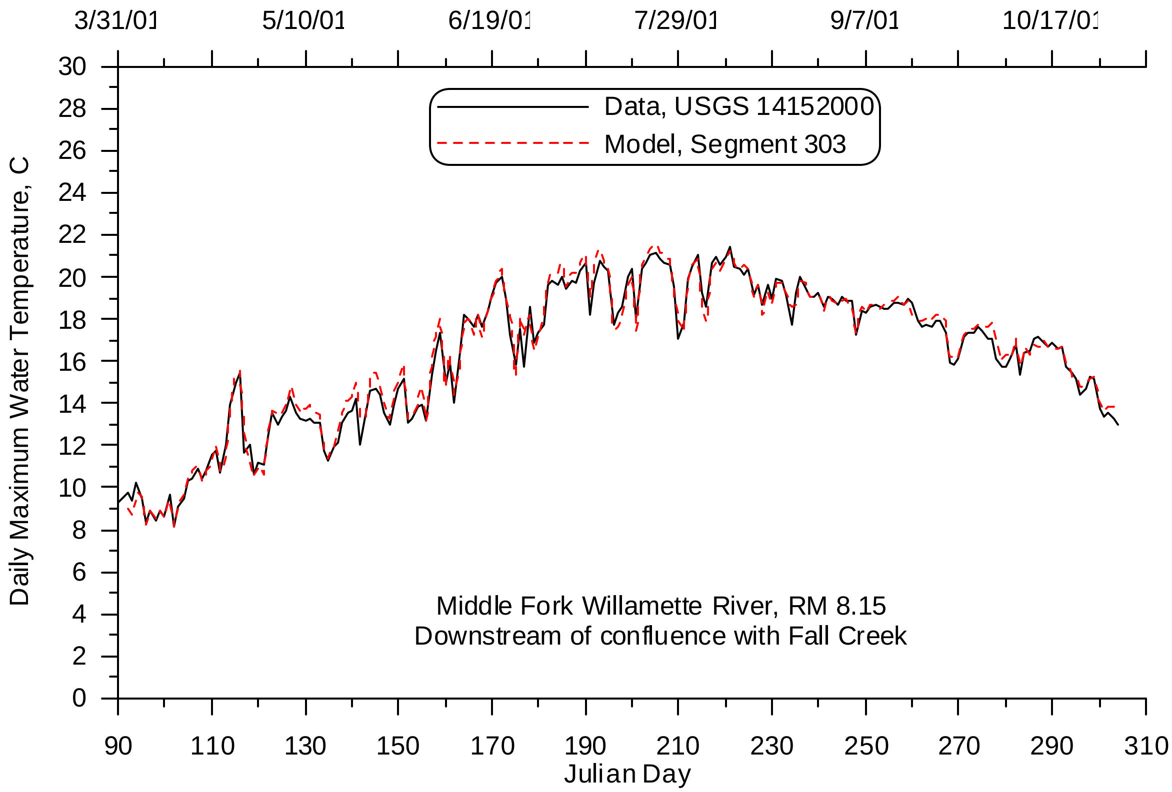

Figure 492: Middle Fork Willamette River at Jasper model-data daily maximum temperature comparison, 2001

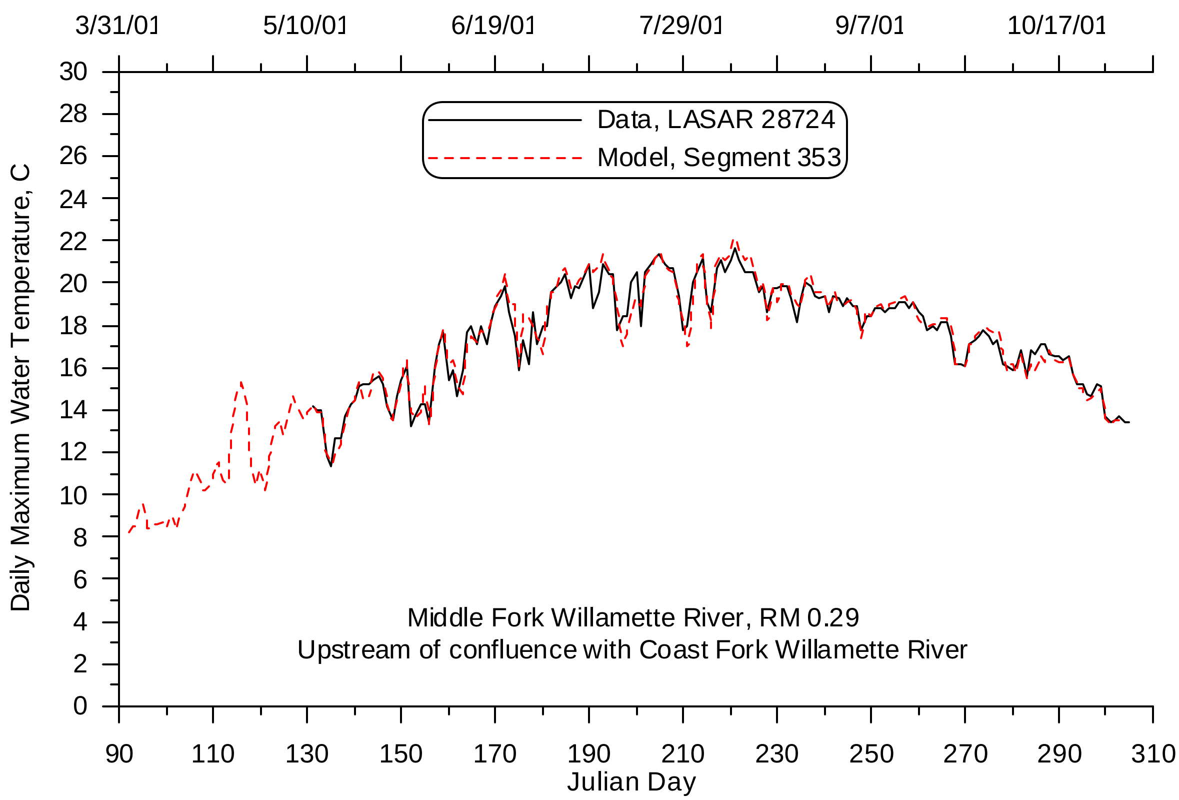

Figure 493: Middle Fork Willamette River near mouth model-data daily maximum temperature comparison, 2001

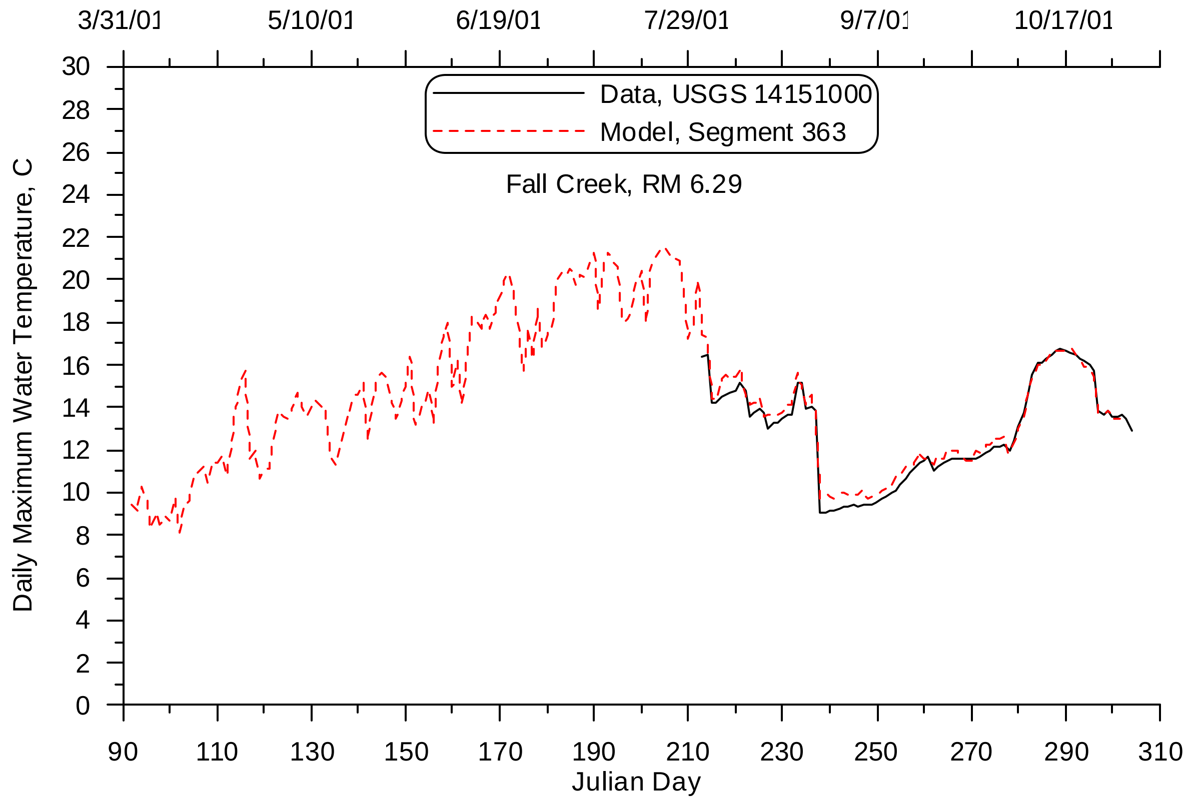

Figure 494: Fall Creek below Winberry Creek model-data daily maximum temperature comparison, 2001

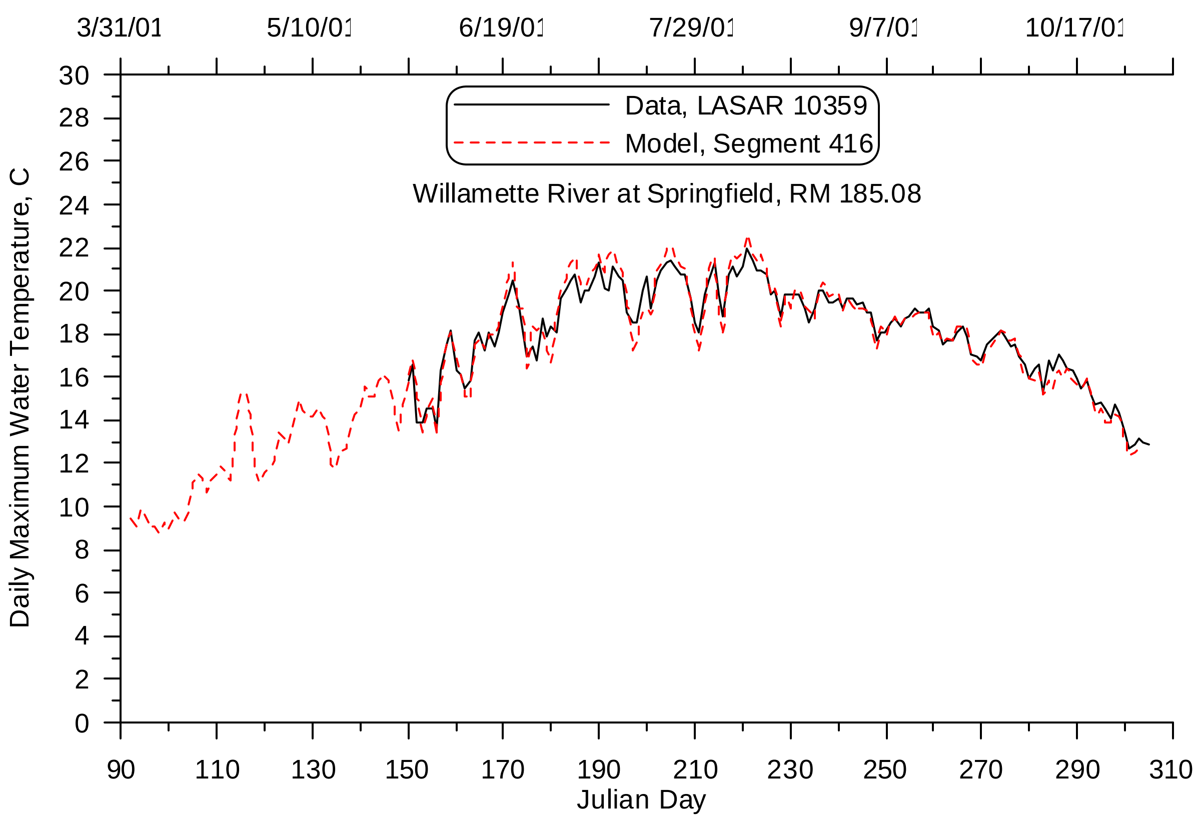

Figure 495: Willamette River at Highway 126 model-data continuous temperature comparison, 2001

Year 2002

Temperatures on the Coast Fork and Middle Willamette River model were calibrated from April through the end of October 2002. Table 73 lists the model-data error statistics for the daily maximum temperature. The table shows absolute mean errors (AME) of less than 1.1 ^oC and root mean square error (RMS) of 1.3 ^oC or less. Overall the mean error shows there is a bias warmer of about 0.3 ^oC.

Figure 496 to Figure 502 show model-data daily maximum temperature comparisons on the Coast Fork Willamette River and Row River. These figures show the model has relative agreement with the data but as shown in the continuous temperature results there are periods when the model is over predicting daily maximum temperatures compared with data.

Figure 503 to Figure 506 show model-data daily maximum temperature comparisons for the Middle Fork Willamette River and Fall Creek. The figures show there is consistently good model-data agreement over the simulation period with the exception of Fall Creek where model results indicate warmer daily maximum temperatures than data.

Figure 507 shows a plot of a daily maximum temperature comparison between the model and data at RM 185.1 on the main stem of the Willamette River. This figure indicates there is good model-data agreement at this site.

Table 73: Coast and Middle Fork Willamette River daily maximum water temperature calibration model-data error statistics, 2002

Site ID	RM	Model Segment	Daily Maximum Temperature			
			Number of Comparisons	ME, ^oC	AME, ^oC	RMS, ^oC
USGS 14153500	28.69	4	210	0.15	0.18	0.24
LASAR 29643	21.60	49	124	0.35	1.02	1.30
LASAR 10381	19.34	63	124	0.60	0.85	1.02
LASAR 10380	12.27	109	124	0.09	0.89	1.08
USGS 14157500	5.72	153	210	-0.38	0.93	1.20
LASAR 10991	6.74	199	127	1.03	1.04	1.26
USGS 14155500	5.51	206	210	0.87	0.89	1.11
USGS 14150000	13.95	264	210	0.15	0.21	0.26
USGS 14152000	8.15	303	210	-0.25	0.36	0.44
LASAR 28724	0.29	353	178	-0.24	0.43	0.52
USGS 14151000	6.29	363	210	0.68	0.70	0.91
LASAR 10359	185.08	416	120	-0.05	0.34	0.45

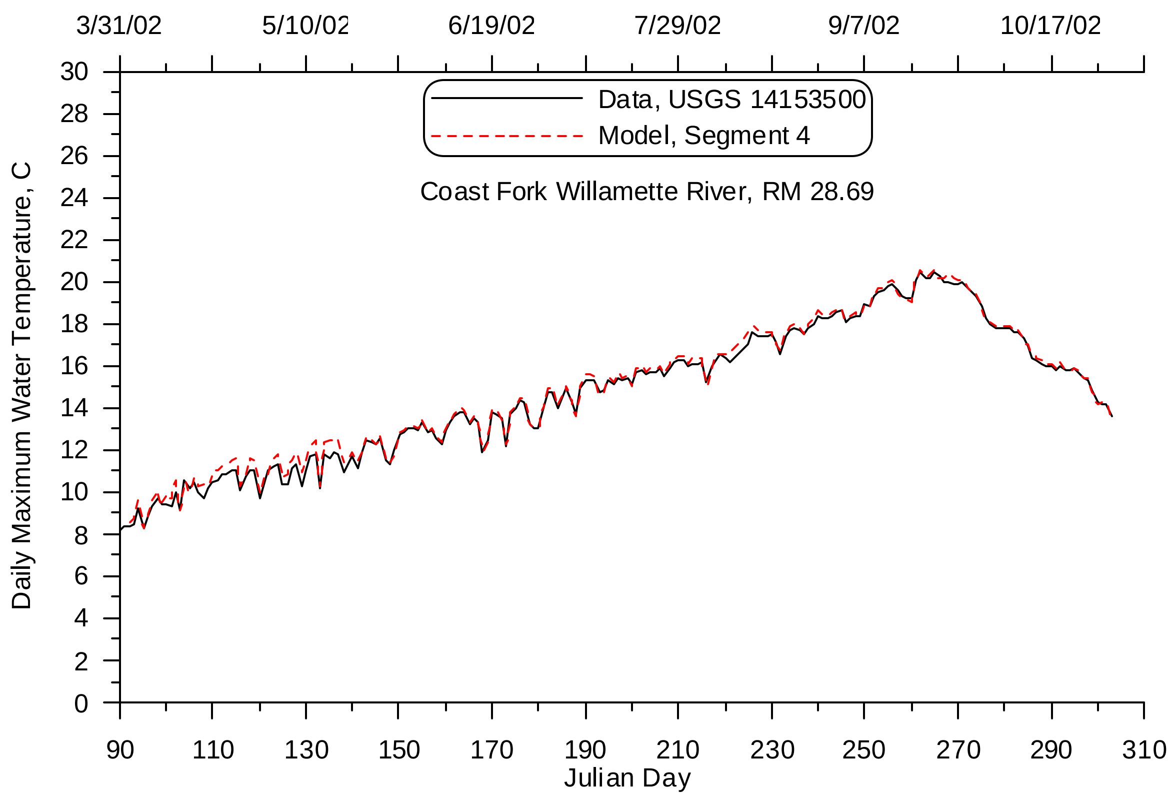

Figure 496: Coast Fork Willamette River below Cottage Grove Dam model-data daily maximum temperature comparison, 2002

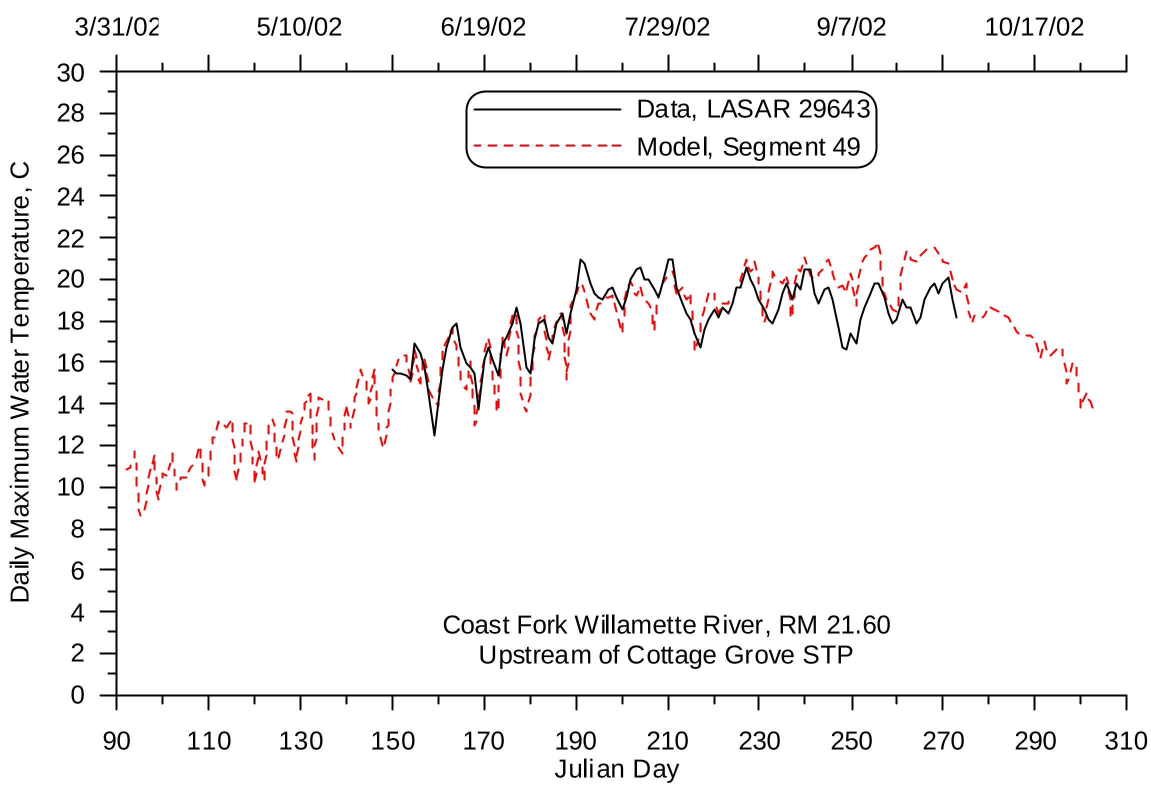

Figure 497: Coast Fork Willamette River above Cottage Grove WWTP model-data daily maximum temperature comparison, 2002

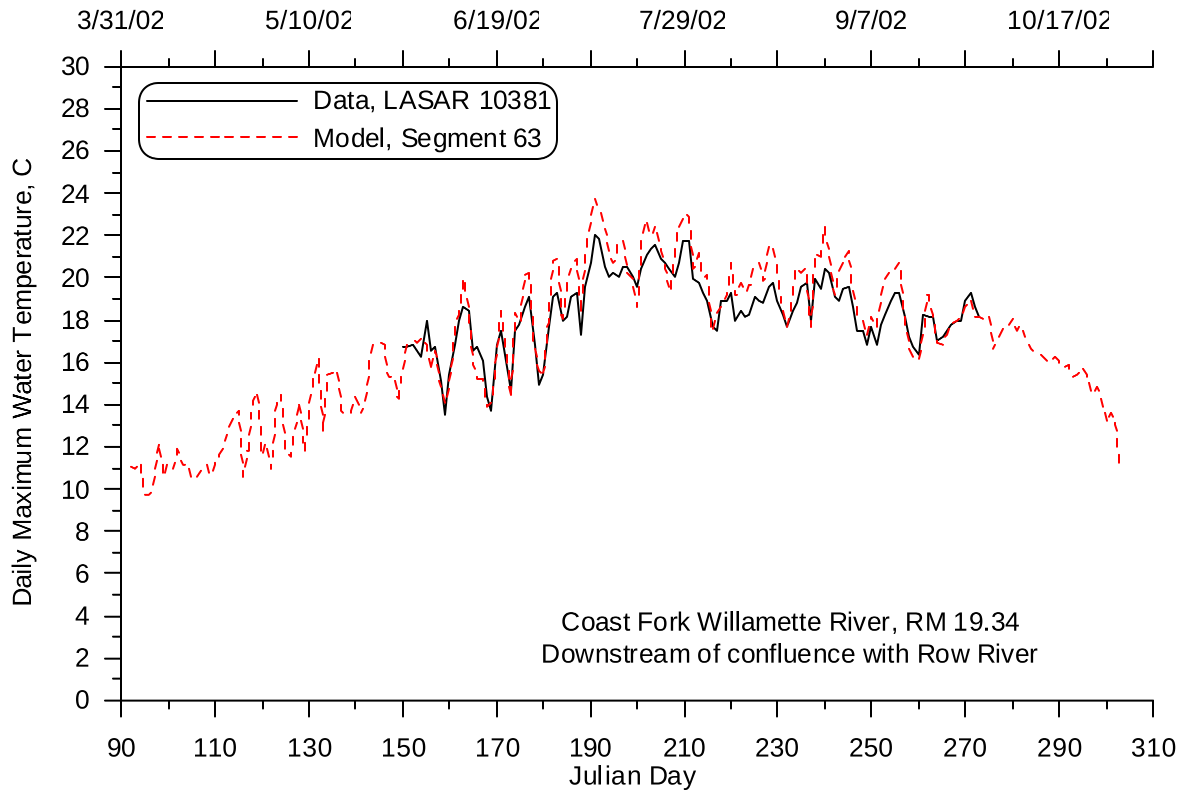

Figure 498: Coast Fork Willamette River at Saginaw Bridge model-data daily maximum temperature comparison, 2002

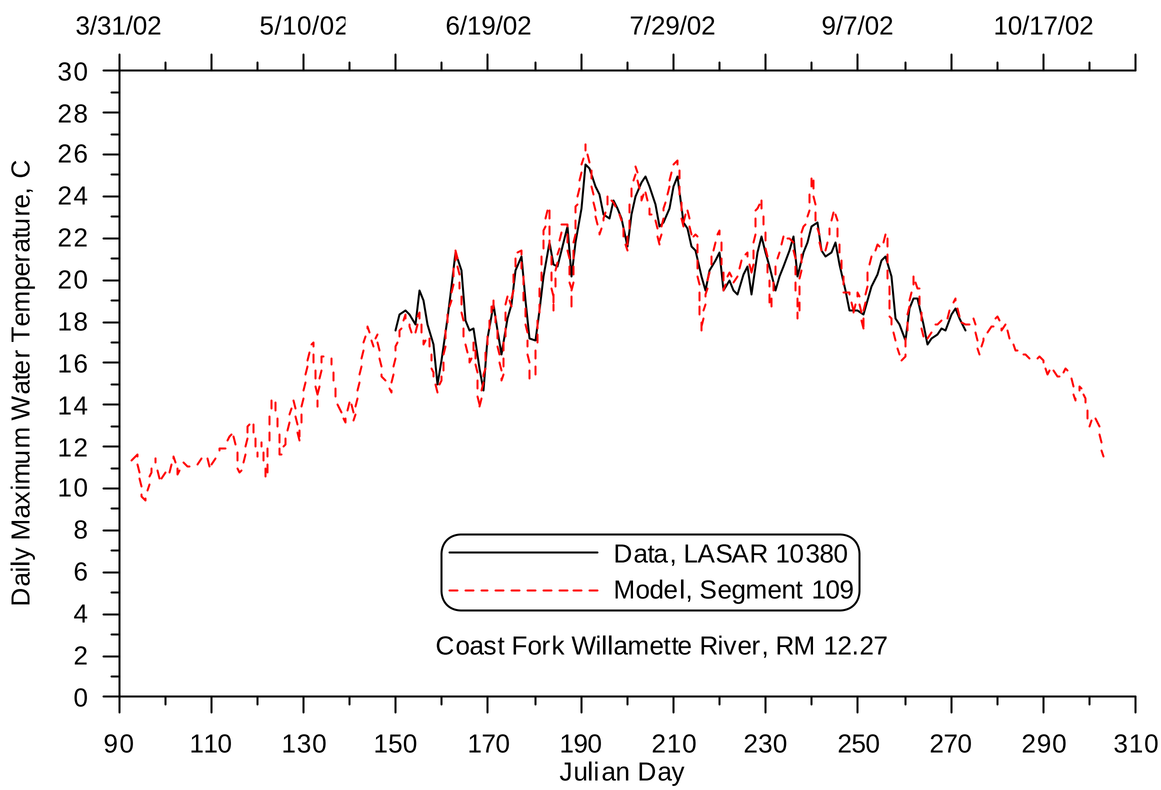

Figure 499: Coast Fork Willamette River at Creswell model-data daily maximum temperature comparison, 2002

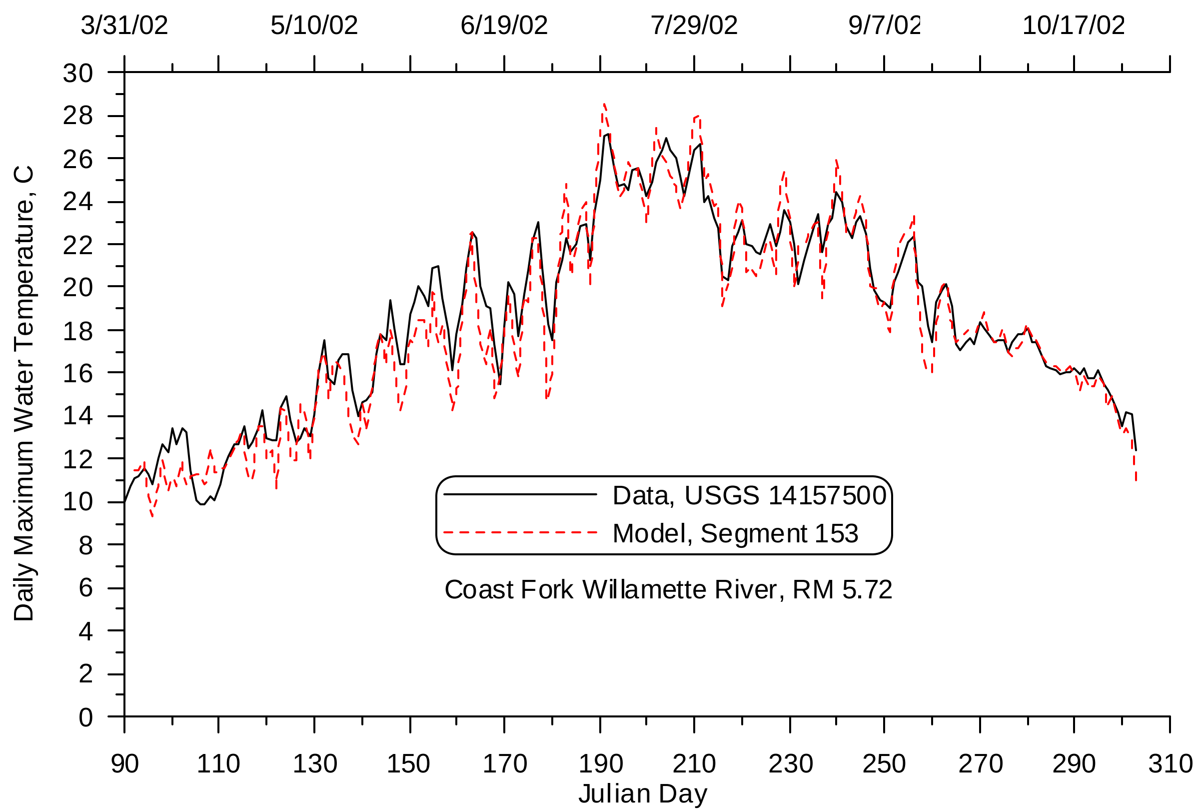

Figure 500: Coast Fork Willamette River near Goshen model-data daily maximum temperature comparison, 2002

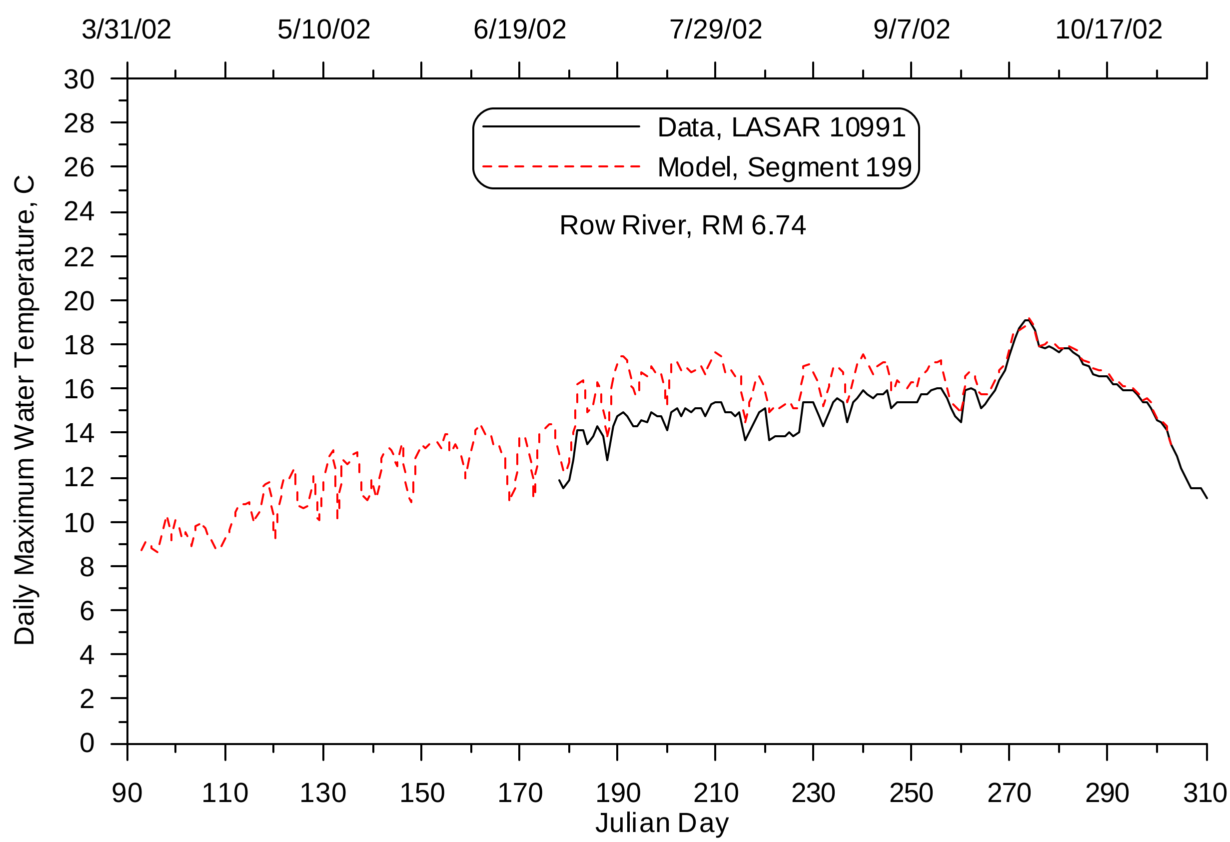

Figure 501: Row River below Dorena Reservoir model-data daily maximum temperature comparison, 2002

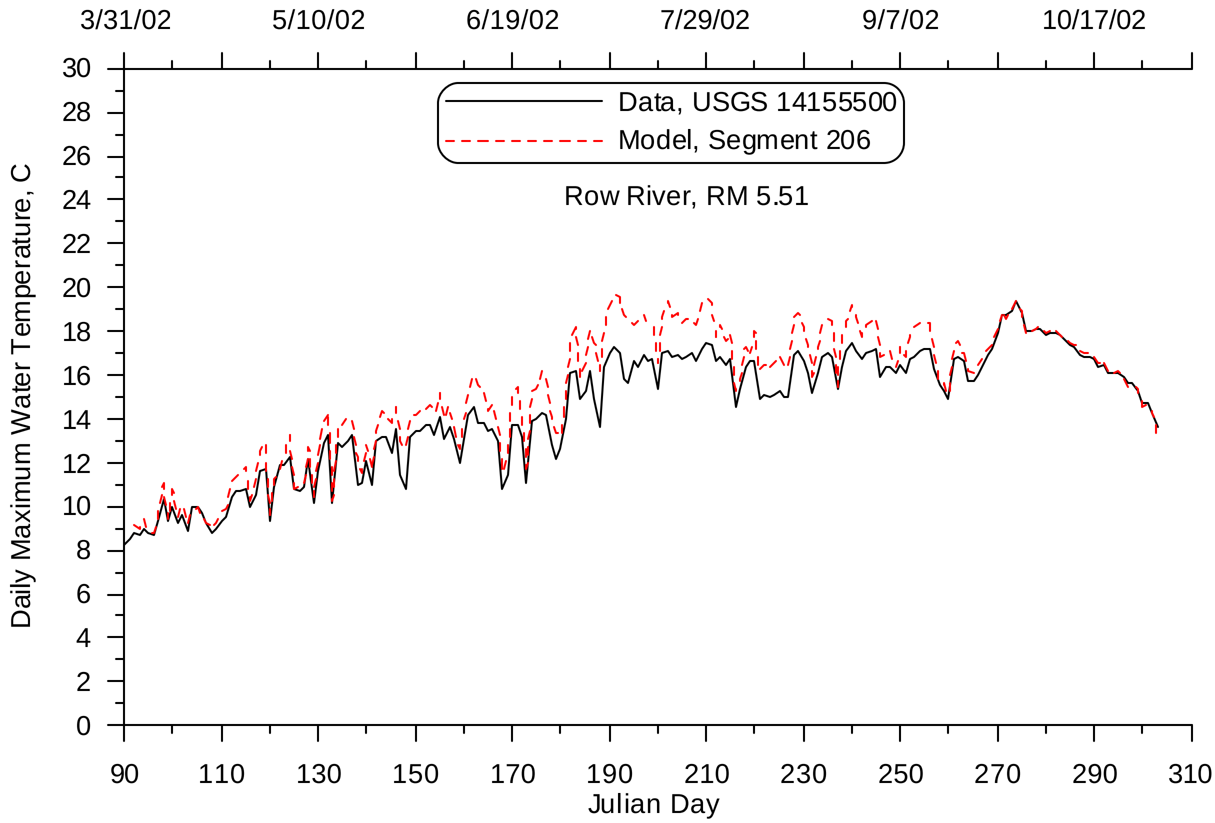

Figure 502: Row River near Cottage Grove model-data daily maximum temperature comparison, 2002

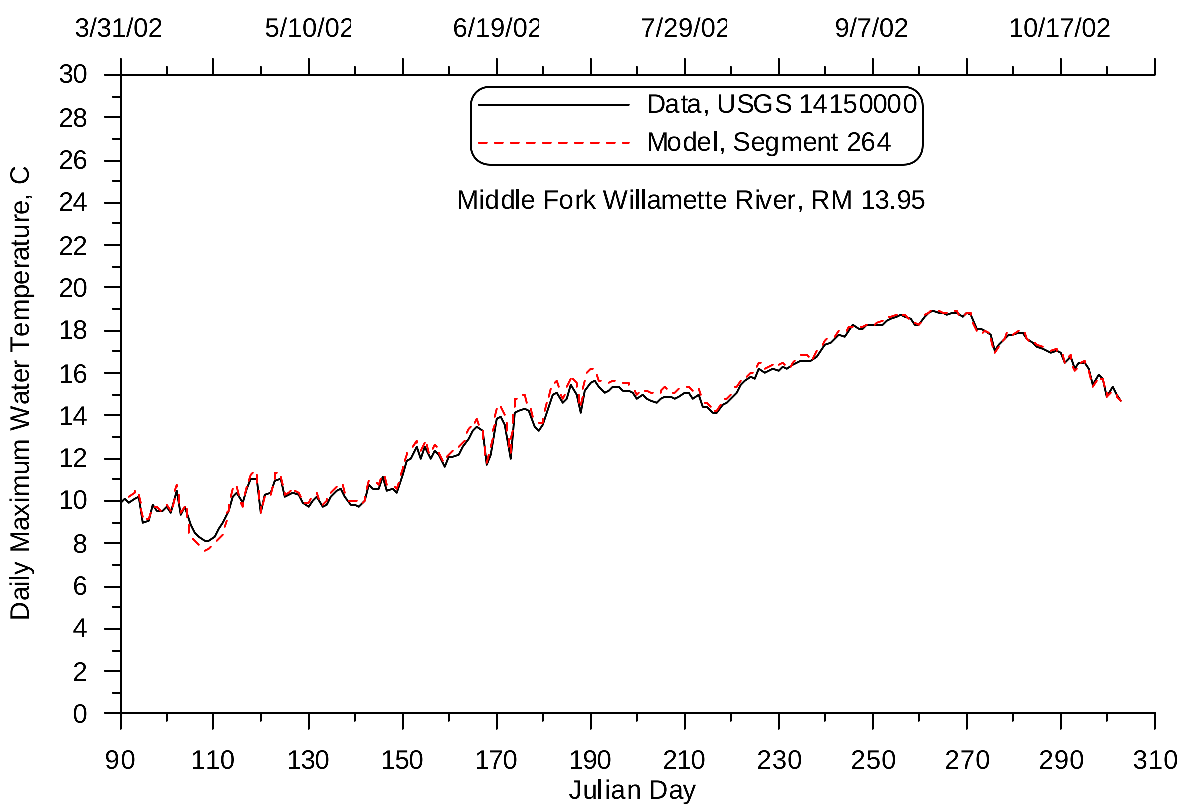

Figure 503: Middle Fork Willamette River near Dexter model-data daily maximum temperature comparison, 2002

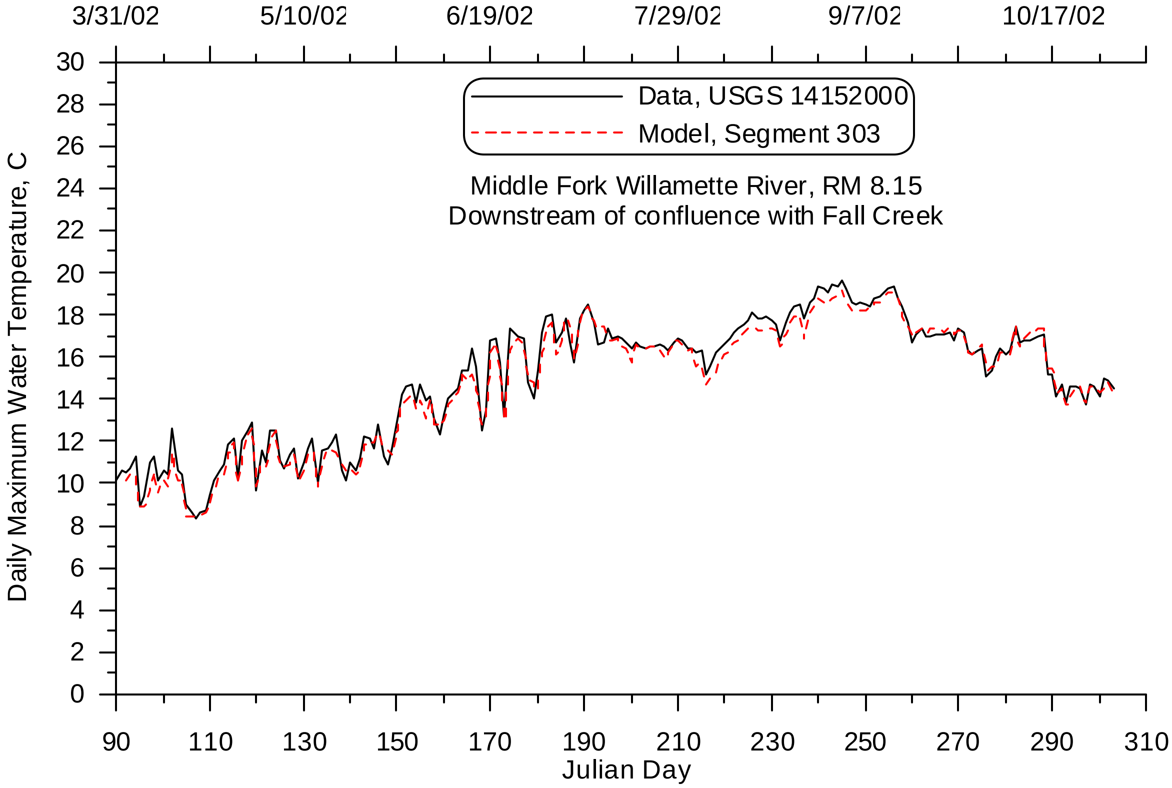

Figure 504: Middle Fork Willamette River at Jasper model-data daily maximum temperature comparison, 2002

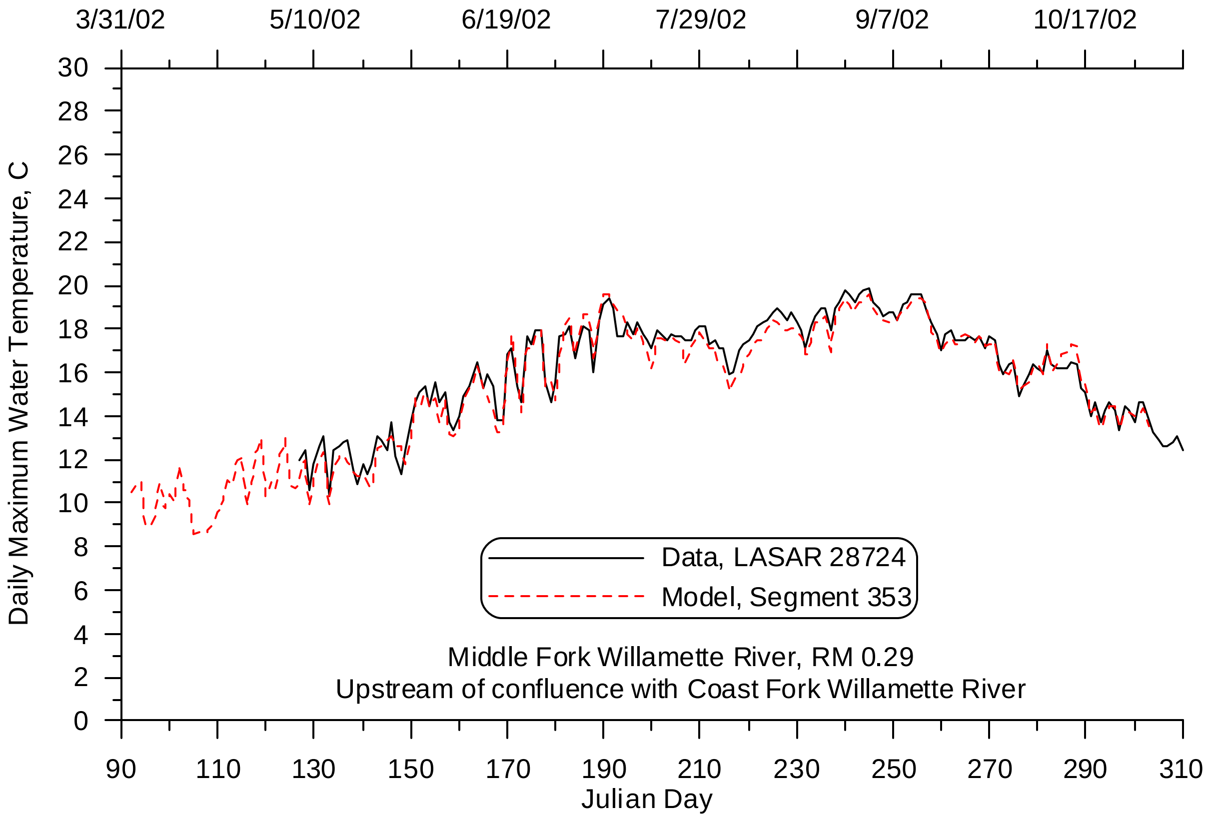

Figure 505: Middle Fork Willamette River near mouth model-data daily maximum temperature comparison, 2002

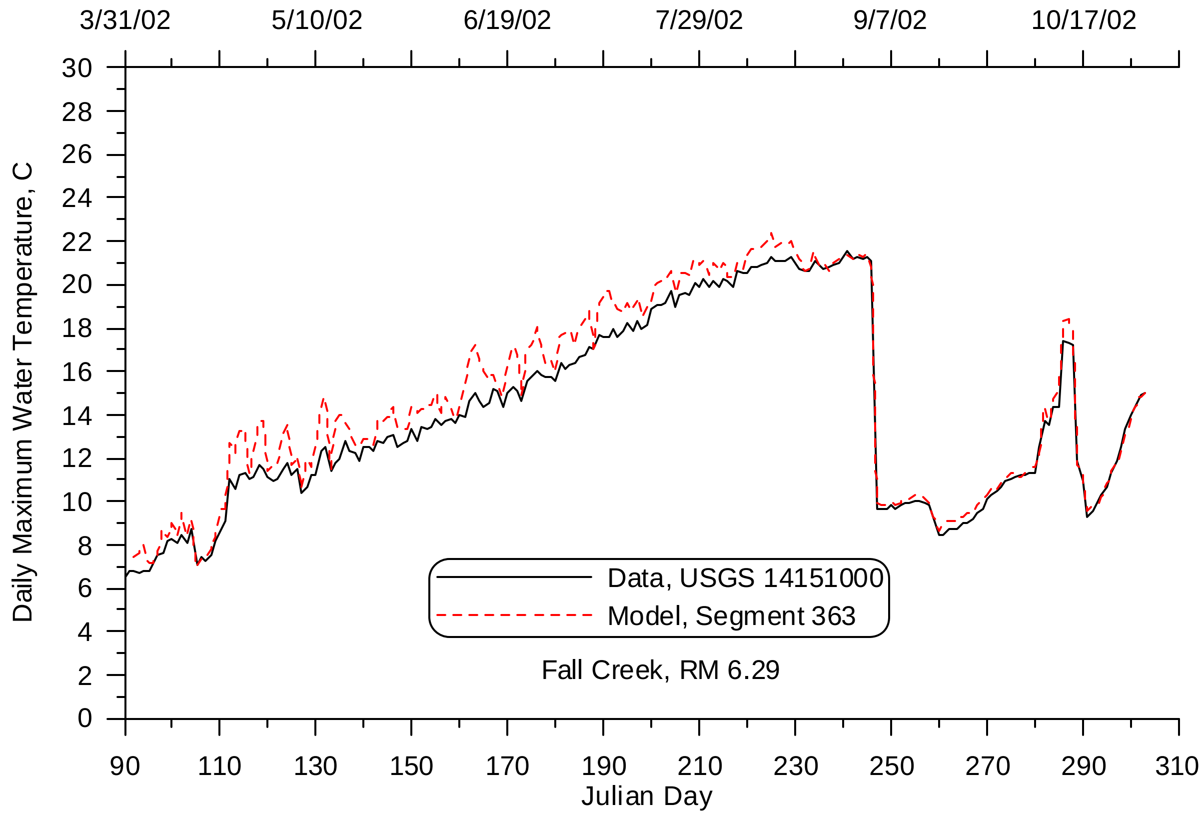

Figure 506: Fall Creek below Winberry Creek model-data daily maximum temperature comparison, 2002

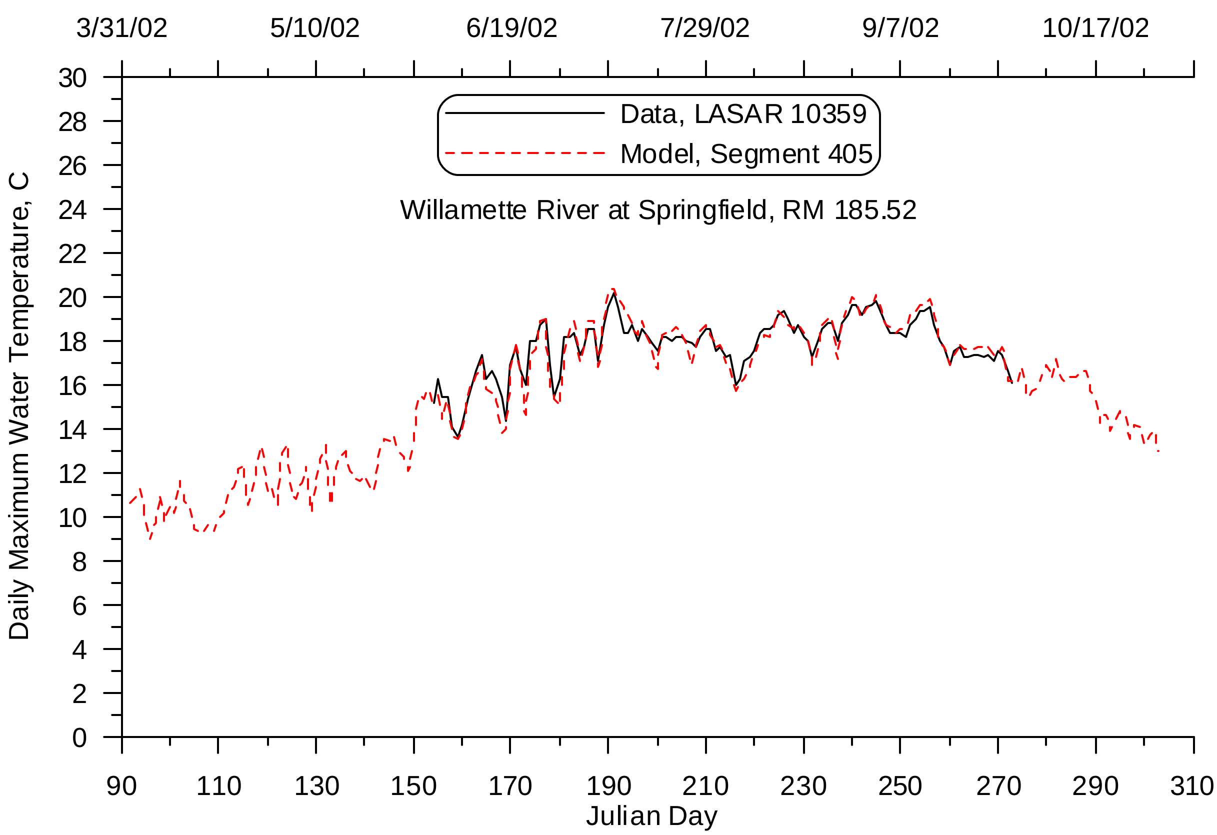

Figure 507: Willamette River at Highway 126 model-data daily maximum temperature comparison, 2002

Summary

This report summarizes work on calibrating the Willamette River basin model during 2001 and 2002. The calibration process included model-data comparisons of

- flow rate at USGS gage stations
- water level usually at flow monitoring gages
- wetted width at different flow rates
- temperature

In general, calibration results were deemed acceptable based on the data for which the model was constructed. A goal of the calibration was to have flow data to be in almost exact agreement, water levels to be within the error of the finest grid resolution, model predicted widths to be similar to field estimates, dye travel times to be in reasonable agreement, and instantaneous AME/RMS errors for temperature below 1^oC. Oftentimes, improving the calibration in one year or for one variable, resulted in worse predictions for other variables or for different years. Hence, a calibration was made for the 2 years that was invariant but where results were reasonable across both years and all model variables.

Most of the calibration effort was not directed toward adjusting model parameters. This was only a small part of the calibration exercise. Most of the effort was directed at representing the system more accurately. One example involved re-evaluating channel morphology and finding that there had been errors in reducing the data from field surveys. Once the new channel morphology was used, model-data predictions improved. This is typical of a good model – the more accurately one describes the prototype, the more accurate the model will be in predicting field data. The goal of such modeling is to reduce the calibration "knobs" available to the modeler since most of the error in modeling is based on poor understanding of boundary conditions and conditions within the model domain.

References

Annear, R. L.; McKillip, M. L.; Khan, Sher Jamal; Berger, C. J.; and Wells, S. A. (2004a) "Willamette River Basin Temperature TMDL Model: Boundary Conditions and Model Setup," Technical Report EWR-01-04, Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

Annear, R. L.; McKillip, M. L.; Khan, Sher Jamal; Berger, C. J.; and Wells, S. A. (2004b) "Willamette River Basin Temperature TMDL Model: Model Scenarios," Technical Report EWR-03-04, Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

Harris, D.D. (1968). "Travel rates of water for selected streams in the Willamette River Basin, Oregon," USGS Hydrologic Investigations, Atlas HA-273.

Appendix 1: Model-Data Error Statistics Calculations

Model error was completed using the following formulas for the mean, absolute mean, and root mean square error:

$$Mean\_Error(ME) = \frac{\sum_{1}^{n}(\text{model} - \text{data})}{n}$$

$$Absolute\_Mean\_Error(AME) = \frac{\sum_{1}^{n} abs(\text{model} - \text{data})}{n}$$

$$Root\_Mean\_Square\_Error(RMS) = \sqrt{\frac{\sum_{1}^{n}(\text{model} - \text{data})^2}{n}}$$

where n is the number of observations, model is the model predicted state variable and data is the filed data variable.